



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

S 64051



HARVARD
COLLEGE
LIBRARY



—

A HISTORY OF THE SCIENCES

Astronomy, by Prof. GEORGE FORBES, M.A., F.R.S.

Chemistry, 2 volumes, by Sir EDWARD THORPE, C.B., LL.D., F.R.S., etc.

Old Testament Criticism, by Prof. ARCHIBALD DUFF (Prof. of Hebrew and Old Testament Theology in the United College, Bradford).

Anthropology, by ALFRED C. HADDON, M.A., Sc.D., F.R.S.

New Testament Criticism, by F. C. CONYBEARE, M.A.

Geology, by H. B. WOODWARD, F.R.S., F.G.S.

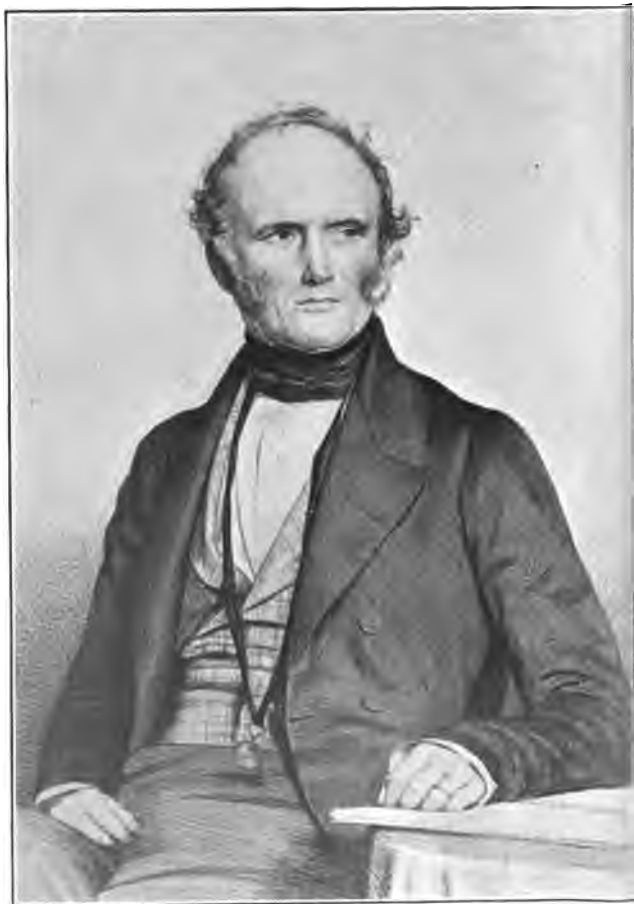
Geography, by Dr. SCOTT KELTIE, F.R.G.S., F.S.A.

Biology, by L. C. MIALL, D.S.C., F.R.S.

G. P. PUTNAM'S SONS

New York

London



SIR CHARLES LYELL
From a portrait by T. H. Maguire

A HISTORY OF THE SCIENCES

HISTORY
OF
GEOLOGY

BY

HORACE B. WOODWARD

F.R.S., F.G.S.

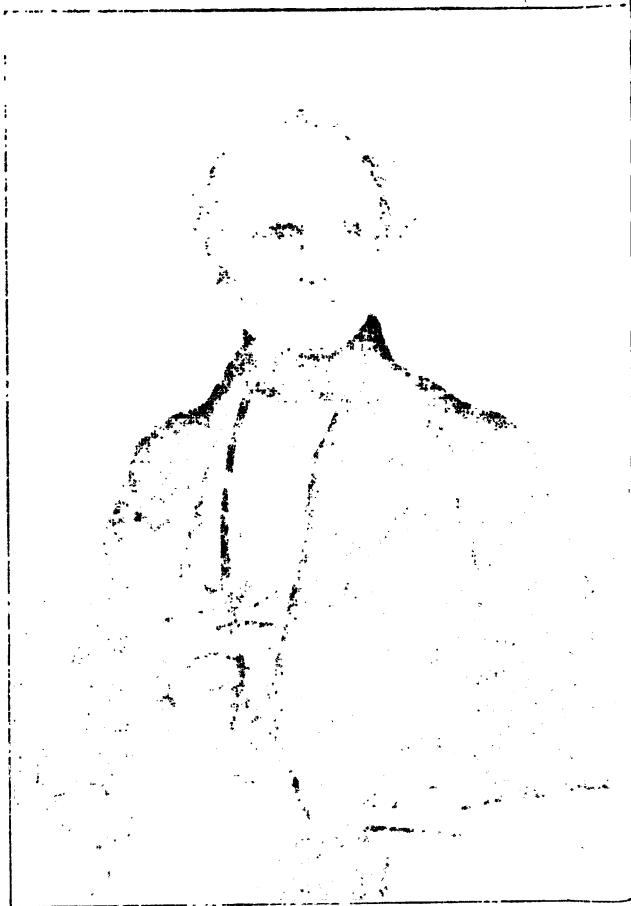
(FORMERLY ASSISTANT-DIRECTOR OF GEOLOGICAL SURVEY OF ENGLAND
AND WALES)

AUTHOR OF "THE GEOLOGY OF ENGLAND AND WALES," "THE HISTORY
OF THE GEOLOGICAL SOCIETY OF LONDON," ETC.

WITH ILLUSTRATIONS

G. P. PUTNAM'S SONS
NEW YORK AND LONDON
The Knickerbocker Press

1911



SIR CHARLES LYELL
From a portrait by T. H. Maguire

A HISTORY OF THE SCIENCES

HISTORY
OF
GEOLOGY

BY

HORACE B. WOODWARD

F.R.S., F.G.S.

(FORMERLY ASSISTANT-DIRECTOR OF GEOLOGICAL SURVEY OF ENGLAND
AND WALES)

AUTHOR OF "THE GEOLOGY OF ENGLAND AND WALES," "THE HISTORY
OF THE GEOLOGICAL SOCIETY OF LONDON," ETC.

WITH ILLUSTRATIONS

G. P. PUTNAM'S SONS
NEW YORK AND LONDON
The Knickerbocker Press

1911

Geol 49.11

✓

S 6725.880

✓



This series is published in London by
THE RATIONALIST PRESS ASSOCIATION, LIMITED

The Knickerbocker Press, New York

PUBLISHERS' NOTE

A HISTORY OF THE SCIENCES has been planned to present for the information of the general public a historic record of the great divisions of science. Each volume is the work of a writer who is accepted as an authority on his own subject-matter. The books are not to be considered as primers, but present thoroughly digested information on the relations borne by each great division of science to the changes in human ideas and to the intellectual development of mankind. The monographs explain how the principal scientific discoveries have been arrived at and the names of the workers to whom such discoveries are due.

The books will comprise each about 200 pages. Each volume will contain from 12 to 16 illustrations, including portraits of the discoverers and explanatory views and diagrams. Each volume contains also a concise but comprehensive bibliography of the subject-matter. A list of the works thus far issued in the series, and those in preparation, will be found at the end of this volume.

CONTENTS

CHAPTER I

	PAGE
EARLY NOTIONS ABOUT THE HISTORY OF THE EARTH	I

CHAPTER II

THE FOUNDERS OF GEOLOGY AS A SCIENCE	32
------------------------------------------------	----

CHAPTER III

GEOLOGY IN THE EARLY PART OF THE NINETEENTH CENTURY	56
------------------------------------------------------------------	----

CHAPTER IV

THE PRINCIPLES OF GEOLOGY	96
-------------------------------------	----

CHAPTER V

LOCAL AND OFFICIAL GEOLOGICAL SURVEYS AND ECONOMIC GEOLOGY	112
-------------------------------------------------------------------------	-----

CHAPTER VI

THE ELUCIDATION OF THE OLDER GEOLOGICAL SYS- TEMS, WITH REMARKS ON THE HISTORY OF THE NEWER SYSTEMS	126
---------------------------------------------------------------------------------------------------------------------	-----

	PAGE
CHAPTER VII	
PALÆONTOLOGY AND THE SUCCESSION OF LIFE . . .	156
CHAPTER VIII	
THE ARCHÆAN AND METAMORPHIC ROCKS. GREAT EARTH MOVEMENTS. PETROLOGY. CONCLUDING REMARKS	178
BIBLIOGRAPHY	189
INDEX	193

ILLUSTRATIONS

	PAGE
SIR CHARLES LYELL (age 52)	<i>Frontispiece</i>
WILLIAM SMITH (age 69)	43
WILLIAM BUCKLAND (age 62)	63
WILLIAM MACLURE (age about 55)	65
JAMES DE CARLE SOWERBY (age about 80)	69
WILLIAM HYDE WOLLASTON (age about 56)	77
LEOPOLD VON BUCH	79
JAMES DWIGHT DANA (age about 70)	111
ADAM SEDGWICK	127
SIR RODERICK IMPEY MURCHISON (age 68)	131
LOUIS AGASSIZ (age about 54)	139
ALCIDE D'ORBIGNY (age 37)	157
JAMES HALL (age 80)	159

	PAGE
ETHELDRED BENETT (age 60)	16

* * Permission to reproduce the portrait of Buckland from *The Life and Correspondence of William Buckland* was kindly granted by his daughter, Mrs. Gordon; and permission to reproduce the portraits of Maclure, Dana, and James Hall from the *History of American Geology*, by Mr. G. P. Merrill, was similarly granted by the author. Portraits of Von Buch, D'Orbigny, and Etheldred Bennett were kindly lent; and a *cliché* of the portrait of William Smith was presented by Dr. Henry Woodward, F.R.S.

HISTORY OF GEOLOGY

CHAPTER I

EARLY NOTIONS ABOUT THE HISTORY OF THE EARTH

GEOLGY, as understood at the present day is the science which seeks to explain the structure and origin of the earth, and the successive changes in scene and life that have diversified its surface in past times. The story is written in the rocks, the minerals, and the fossils which form the solid outer portion, known as the earth's crust.

As a science, the birth of geology dates from the close of the eighteenth century, when the true method of interpreting the facts had been established. As in other branches of learning, the knowledge which led to the foundation of geology was acquired by degrees, sometimes at long intervals; but many of the observations on which are based the principles of the science were of necessity or even forcibly brought to

the notice of mankind in the earliest days of human existence.

Thus the phenomena of volcanoes and earthquakes, the darkness caused by the dispersal of volcanic dust, hot springs, floods, landslips, and the waste of the land by sea, naturally came under observation; and eventually there arose notions about central heat, of waters under the earth, of successive catastrophes, and periods of destruction and creation.

Attention must have been given in early days to various stones from beach, bed of stream, or bank of gravel, where materials suitable for weapons and implements could be obtained. There, too, bright precious stones and metals would also attract notice, and be used as ornaments and charms.

In course of time the digging of shallow pits for hut circles and of trenches for earthworks, the excavations for rock-shelters and others in the shape of shafts, to provide secret places of refuge and storage (Dene holes) or to extract flint for weapons, all gave ideas of the different kinds of earth and rock, and occasionally proved the presence of well-water.

The discovery in some places of huge fossil bones led to the supposition that there were giants in the days of old, as well as other fabulous creatures. Thus the inhabitants of Klagenfurt preserved in the Rath-Haus a fossil skull

of rhinoceros, believed at one time to be a remnant of their old enemy the famous Dragon, of which a bronze effigy adorns their public square.¹

The digging of clay for pottery, the quarrying of stone for building, as well as agricultural operations, gave knowledge of the soils and substrata; but the earliest industry connected with geology was doubtless the fabrication of stone weapons. No wonder that curiosity and interest in the origin of the earth and its inhabitants arose at the most remote times of which we have record; that speculations on cosmogony are found in the earliest writings of Oriental nations. Rich in interest, these early efforts of man to penetrate the mystery of the origin of the earth indicate that his aims and aspirations differed in no essential features from those of later and more enlightened generations.

The Philosophers of Greece and Rome

By a study of the teachings and writings of philosophers of old, and especially those of Greece, it is possible to find, in selected passages, the germs of many views and conclusions that have since been established. It is, however,

¹ *Geol. Mag.*, 1864, p. 38.

often as difficult as it is at the present day to determine who first stated a particular view, because doctrines were transmitted orally, and Greek and Roman alike quoted from previous observers. As remarked by Julius Schvarcz (1868), those philosophers "contributed, for the most part of course unwillingly, or at least unconsciously, to the foundation of geology, by collecting data of modern changes within the range of their own observation."

Thus Pythagoras (about 500 B.C.) called attention to evidences of physical changes in the upheaval and depression of land, in the excavation of valleys by running water; and he remarked on the fiery state of the earth's interior. Xenophanes of Colophon, at about the same period, noticed the occurrence of fossil shells and fishes in deposits on mountains. Similar facts, and the presence of fossil fishes in stone pits, were noted by Herodotus (about 440 B.C.), by Aristotle a century later (384-322 B.C.), and others; and they were impressed by the changes ever going on in the deposition of sediment by rivers such as the Nile, by inundations of the sea, and by the phenomena of earthquakes and volcanoes.

Theophrastus (about 300 B.C.), who wrote on the stony as apart from the metallic minerals, appears to have started the notion that organised fossils were due to a plastic virtue latent

in the earth—an unphilosophical notion which was adopted by some subsequent naturalists who ought to have known better.

Strabo (about 20 B.C.) and Pliny the elder (23-79 A.D.) drew attention to many geographical changes, and Strabo noted that earthquakes were less prominent when volcanoes were active. Pliny recognised the definite forms of crystals. He lost his life during the eruption of Vesuvius in 79 A.D., when Herculaneum was overwhelmed by volcanic mud and lava, and Pompeii by dust, ashes, and pumice.

In those early days a knowledge of the forces of nature was acquired; but, while the changes due to the occurrence of sea-shells at high elevations were attributed by some philosophers to the depression and upheaval of land, nothing was known of the sequence of rocks and fossils.

Lucretius, in the earlier half of the first century B.C., has been credited with ideas about the struggle for existence among the forms of life and the survival of the fittest.¹ About the same period Diodorus Siculus referred to philosophers who taught the gradual formation of the world from a state of chaos. Some evidently regarded the features as practically permanent, and the hills as everlasting; while

¹ Dr. E. Walker, *Lond. Quart. Rev.*, 1909, p. 246.

CONTENTS

CHAPTER I

	PAGE
EARLY NOTIONS ABOUT THE HISTORY OF THE EARTH	I

CHAPTER II

THE FOUNDERS OF GEOLOGY AS A SCIENCE . . .	32
--------------------------------------------	----

CHAPTER III

GEOLOGY IN THE EARLY PART OF THE NINETEENTH CENTURY	56
------------------------------------------------------------------	----

CHAPTER IV

THE PRINCIPLES OF GEOLOGY	96
-------------------------------------	----

CHAPTER V

LOCAL AND OFFICIAL GEOLOGICAL SURVEYS AND ECONOMIC GEOLOGY	112
-------------------------------------------------------------------------	-----

CHAPTER VI

THE ELUCIDATION OF THE OLDER GEOLOGICAL SYS- TEMS, WITH REMARKS ON THE HISTORY OF THE NEWER SYSTEMS	126
---------------------------------------------------------------------------------------------------------------------	-----

	PAGE
CHAPTER VII	
PALÆONTOLOGY AND THE SUCCESSION OF LIFE . . .	156
CHAPTER VIII	
THE ARCHÆAN AND METAMORPHIC ROCKS. GREAT EARTH MOVEMENTS. PETROLOGY. CONCLUDING REMARKS	178
BIBLIOGRAPHY	189
INDEX	193

ILLUSTRATIONS

	PAGE
SIR CHARLES LYELL (age 52)	<i>Frontispiece</i>
WILLIAM SMITH (age 69)	43
WILLIAM BUCKLAND (age 62)	63
WILLIAM MACLURE (age about 55)	65
JAMES DE CARLE SOWERBY (age about 80)	69
WILLIAM HYDE WOLLASTON (age about 56)	77
LEOPOLD VON BUCH	79
JAMES DWIGHT DANA (age about 70)	111
• ADAM SEDGWICK	127
SIR RODERICK IMPEY MURCHISON (age 68)	131
LOUIS AGASSIZ (age about 54)	139
ALCIDE D'ORBIGNY (age 37)	157
JAMES HALL (age 80)	159

	PAGE
ETHELDRED BENETT (age 60)	162

* * Permission to reproduce the portrait of Buckland from *The Life and Correspondence of William Buckland* was kindly granted by his daughter, Mrs. Gordon; and permission to reproduce the portraits of Maclure, Dana, and James Hall from the *History of American Geology*, by Mr. G. P. Merrill, was similarly granted by the author. Portraits of Von Buch, D'Orbigny, and Etheldred Benett were kindly lent; and a *cliché* of the portrait of William Smith was presented by Dr. Henry Woodward, F.R.S.

HISTORY OF GEOLOGY

CHAPTER I

EARLY NOTIONS ABOUT THE HISTORY OF THE EARTH

GEOLGY, as understood at the present day is the science which seeks to explain the structure and origin of the earth, and the successive changes in scene and life that have diversified its surface in past times. The story is written in the rocks, the minerals, and the fossils which form the solid outer portion, known as the earth's crust.

As a science, the birth of geology dates from the close of the eighteenth century, when the true method of interpreting the facts had been established. As in other branches of learning, the knowledge which led to the foundation of geology was acquired by degrees, sometimes at long intervals; but many of the observations on which are based the principles of the science were of necessity or even forcibly brought to

the notice of mankind in the earliest days of human existence.

Thus the phenomena of volcanoes and earthquakes, the darkness caused by the dispersal of volcanic dust, hot springs, floods, landslips, and the waste of the land by sea, naturally came under observation; and eventually there arose notions about central heat, of waters under the earth, of successive catastrophes, and periods of destruction and creation.

Attention must have been given in early days to various stones from beach, bed of stream, or bank of gravel, where materials suitable for weapons and implements could be obtained. There, too, bright precious stones and metals would also attract notice, and be used as ornaments and charms.

In course of time the digging of shallow pits for hut circles and of trenches for earthworks, the excavations for rock-shelters and others in the shape of shafts, to provide secret places of refuge and storage (Dene holes) or to extract flint for weapons, all gave ideas of the different kinds of earth and rock, and occasionally proved the presence of well-water.

The discovery in some places of huge fossil bones led to the supposition that there were giants in the days of old, as well as other fabulous creatures. Thus the inhabitants of Klagenfurt preserved in the Rath-Haus a fossil skull

of rhinoceros, believed at one time to be a remnant of their old enemy the famous Dragon, of which a bronze effigy adorns their public square.¹

The digging of clay for pottery, the quarrying of stone for building, as well as agricultural operations, gave knowledge of the soils and substrata; but the earliest industry connected with geology was doubtless the fabrication of stone weapons. No wonder that curiosity and interest in the origin of the earth and its inhabitants arose at the most remote times of which we have record; that speculations on cosmogony are found in the earliest writings of Oriental nations. Rich in interest, these early efforts of man to penetrate the mystery of the origin of the earth indicate that his aims and aspirations differed in no essential features from those of later and more enlightened generations.

The Philosophers of Greece and Rome

By a study of the teachings and writings of philosophers of old, and especially those of Greece, it is possible to find, in selected passages, the germs of many views and conclusions that have since been established. It is, however,

¹ *Geol. Mag.*, 1864, p. 38.

often as difficult as it is at the present day to determine who first stated a particular view, because doctrines were transmitted orally, and Greek and Roman alike quoted from previous observers. As remarked by Julius Schvarcz (1868), those philosophers "contributed, for the most part of course unwillingly, or at least unconsciously, to the foundation of geology, by collecting data of modern changes within the range of their own observation."

Thus Pythagoras (about 500 B.C.) called attention to evidences of physical changes in the upheaval and depression of land, in the excavation of valleys by running water; and he remarked on the fiery state of the earth's interior. Xenophanes of Colophon, at about the same period, noticed the occurrence of fossil shells and fishes in deposits on mountains. Similar facts, and the presence of fossil fishes in stone pits, were noted by Herodotus (about 440 B.C.), by Aristotle a century later (384-322 B.C.), and others; and they were impressed by the changes ever going on in the deposition of sediment by rivers such as the Nile, by inundations of the sea, and by the phenomena of earthquakes and volcanoes.

Theophrastus (about 300 B.C.), who wrote on the stony as apart from the metallic minerals, appears to have started the notion that organised fossils were due to a plastic virtue latent

in the earth—an unphilosophical notion which was adopted by some subsequent naturalists who ought to have known better.

Strabo (about 20 B.C.) and Pliny the elder (23-79 A.D.) drew attention to many geographical changes, and Strabo noted that earthquakes were less prominent when volcanoes were active. Pliny recognised the definite forms of crystals. He lost his life during the eruption of Vesuvius in 79 A.D., when Herculaneum was overwhelmed by volcanic mud and lava, and Pompeii by dust, ashes, and pumice.

In those early days a knowledge of the forces of nature was acquired; but, while the changes due to the occurrence of sea-shells at high elevations were attributed by some philosophers to the depression and upheaval of land, nothing was known of the sequence of rocks and fossils.

Lucretius, in the earlier half of the first century B.C., has been credited with ideas about the struggle for existence among the forms of life and the survival of the fittest.¹ About the same period Diodorus Siculus referred to philosophers who taught the gradual formation of the world from a state of chaos. Some evidently regarded the features as practically permanent, and the hills as everlasting; while

¹ Dr. E. Walker, *Lond. Quart. Rev.*, 1909, p. 246.

others were more impressed with the evidence of slow but perpetual changes.

During the Roman occupation of Britain gold was worked near Pumpsaint, in Carmarthenshire; but the occurrence of this and ores of other metals, such as copper, tin, lead, and iron, was known to the Britons. Zinc ore and coal were probably first found in England by the Romans. Coal was known to Theophrastus. Observations in Britain during the Roman period, whether on metals, building-stones, or clays, were of a purely practical nature.

Mediæval Science

During the Middle Ages the records of the growth of knowledge relating to the earth are comparatively meagre. Much further practical knowledge must, however, have been acquired in the excavations made for building materials and other products of economic value.

The term "fossil" was originally applied to any "shaped-stone" dug out of the earth, whether mineral, shell, or other organic remains. It was long before the name became restricted to the fossil relics of plants and animals. True fossils attracted some attention in monasteries and other religious establishments, as rosaries were made from the stem-joints of encrinites,

strung together and known as St. Cuthbert's Beads.

Mineralogy was cultivated in the tenth century by Arabian sages, among whom AVICENNA, a physician, wrote on the formation and classification of minerals.

Omar Khayyám, the Persian poet and astronomer, who died about 1123, wrote a work on the retreat of the sea, as recorded by Lyell, basing his views on ancient Indian and Persian charts, and on the evidence of salt springs and marshes in the interior of Asia. It is noteworthy that "his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors, to avoid which persecution he went into voluntary banishment from Samarkand."

The little real progress in scientific knowledge made in Britain up to the fourteenth and fifteenth centuries has been attributed in some measure to the fact that "the majority of our men of intellect were drawn into the monasteries."¹ It is not, therefore, surprising, as Mr. Edward Greenly has remarked, that "the scientific knowledge of the Greeks will compare very favourably indeed with that of the sixteenth century of our era."²

¹ See review of *The Family and the Nation*, by W. C. D. and C. D. Whetham, *Nature*, January 13, 1910, p. 305.

² *The R. P. A. Annual*, 1909.

Science in the Fifteenth and Sixteenth Centuries

To the introduction of printing, after the middle of the fifteenth century, must be attributed the great impetus given to learning, though we may discern no evidence of development in the mental capacity over the great philosophers of Greece and Rome. Many facts were, however, recorded in a promiscuous way, some with shrewd and rational explanations, others accompanied by ludicrous hypotheses.

Among the observers in the fifteenth and sixteenth centuries, the celebrated painter LEO-NARDO DA VINCI (1452-1519) recognised that fossil shells were the remains of once living organisms, and indicated changes in the relations of sea and land. Frascatoro, about the year 1517, took the same view about the nature of fossils, and argued from the positions in which they often occurred that they could not, in general, be due to the Mosaic deluge.

The foot-hills bordering the Apennines are composed of strata that yield many well-preserved mollusca of genera, and even of species, now existing. It is, therefore, not difficult to understand why sound views were expressed by many of the old Italian writers on the nature of fossil sea-shells.

Many fossils discovered in different parts of Europe differed greatly from any known living forms, and on this account their true nature was not discerned. It is, however, astonishing to learn that for three centuries the origin of fossils was a subject of dispute, some naturalists maintaining that they were sports or freaks of nature (*lusus naturæ*), due to a kind of "lapidifying juice," or to the "tumultuous movements of terrestrial exhalations"; while, again, certain writers who recognised their organic origin attributed all to the Noachian deluge. Only a few inferred that some fossiliferous strata were not due to that cause.

In the sixteenth century Georg Agricola (or Bauer, 1494-1555) did much to advance knowledge on the subjects of minerals, as distinguished by their external characters, and of metalliferous veins. He gave an illustration in his great work *De Re Metallica* (1556) of the use of the divining rod in the search for ores. He has been termed the "Father of Metallurgy."

In Switzerland, Conrad Gesner (1516-1565) was the author of a work, *De omne Rerum Fossilium genere, Gemmis, Lapidibus, Metallis, et hujusmodi*, published in 1565; and this appears to have been the first descriptive and illustrated work dealing with fossils.

Bernard Palissy, the famous potter, in 1580,

was the first in France to maintain that fossil shells and fishes were remains of animals that formerly existed in the sea.

Of systematic observation on the range of strata, the earliest work of importance was that of George Owen, of Henllys, who in 1570 wrote an essay on the History of Pembrokeshire. This was published more than two centuries later in the Cambrian Register for 1796. As remarked by Buckland and Conybeare, "what chiefly distinguishes this memoir is the observation that the mineral masses constituting the earth's surface are not thrown together promiscuously, but are arranged in a regular order, and in continuous lines, over extensive districts." Owen traced the bands of limestone known as carboniferous limestone, and the adjacent Coal-measures, not only through southern Pembrokeshire, but eastwards through Glamorganshire.¹

Science in the Seventeenth Century

In the seventeenth century STENO (1631-1686), a Dane, who became Professor of Anatomy at Padua, published in 1669 a work in which he described the occurrence of marine and freshwater deposits, recognising that fossils had formerly existed, and that there were

¹ *Trans. Geol. Soc.*, ser. ii., vol. i. (1824), p. 312.

successive strata, the inclined position of which was due to disturbance. His observations on the distribution of fossils were in the main topographic, but he inferred that some rocks had been formed prior to the existence of life. He also observed the constancy in the angles of crystals.¹

John Aubrey, F.R.S. (1626–97), in his *Natural History of Wiltshire*, written between 1656 and 1691, observed: “I have often times wished for a mappe of England, coloured according to the colours of the earth; with markes of the fossiles and minerals.” He also—and perhaps for the first time—remarked on the relations of the rocks to the character of the inhabitants. North Wiltshire being “a dirty clayey country,” the *Indigenæ* were said to be slow and dull, and heavy of spirit, melancholy, contemplative, and malicious; “by consequence whereof come more law suites out of North Wilts, at least double to the southern parts”—a region composed largely of chalk.

TO MARTIN LISTER, M.D. (1638–1712), is generally attributed the first practical suggestion of a geological map. He brought before the Royal Society in 1684 “an ingenious proposal for a new sort of maps of countries, together with tables of sands and clays, such as are

¹ For an appreciation of Steno's work see Sollas (1907), p. 219.

chiefly found in the north parts of England.” He recognised that the geographical distribution of different strata could be represented on maps. Although a naturalist, and distinguished as a conchologist, he regarded fossil shells as “cockle-like stones,” that “never were any part of an animal.”

ROBERT HOOKE, M.D. (1635–1703), “Curator of Experiments” to the Royal Society, brought before that Society, in 1688 and subsequent years, *Discourses of Earthquakes*, in which he dealt with volcanoes, the elevation of land, and other subjects of geological interest, remarking that fossils were truly organic, and more certain tokens of antiquity than coins or medals; and, though difficult, he considered it would not be impossible to raise a chronology out of them. He recognised that turtles formerly occurred in England, evidently from the remains of these reptiles found in the London clay of Sheppey; and, concluding that torrid conditions must have at one time prevailed, he speculated on possible changes in the earth’s axis of rotation to account for the altered climate.

The earliest published reference to geology in England appears to be that in the title of a book by Erasmus Warren, Rector of Worlington, in Suffolk—*Geologia; or, a Discourse Concerning the Earth before the Deluge* (4to, London, 1690); but it is not a work of any scientific value. Ac-

According to the *New English Dictionary*, the word "Geologia" was used in the fourteenth century by Richard de Bury, and in a work by F. Sessa, *Geologia del Dottore*, published at Naples in 1687.

ROBERT PLOT (1640-1696), the first keeper of the Ashmolean Museum at Oxford, published in 1677 *The Natural History of Oxfordshire*, with figures of 300 fossils, which he considered due, like Theophrastus of old, to a "plastic virtue latent in the earth."

Plot's successor, EDWARD LHWYD (1660-1709), dealt more particularly with the fossils of the country around Oxford and other parts of England, in a work entitled *Lithophylacii Britannici Ichnographia*, issued in 1699, and accompanied by many plates of fossils. He noted the occurrence of certain fossils in different strata.

Meanwhile, JOHN WOODWARD, M.D. (1665-1728),¹ who was Professor of Physick in Gresham College, published in 1695 *An Essay toward a Natural History of the Earth*, of which a second edition was issued in 1702. He evidently pursued his studies in a very systematic manner, for he remarked:

And wheresoever I had notice of any considerable *natural Spelunca* or *Grotto*: any sinking of *Wells*: or digging for *Earths*,

¹ He was one of the few geologists buried in Westminster Abbey. Others were Buckland and Lyell.

Clays, Marle, Sand, Gravel, Chalk, Cole, Stone, Marble, Ores of Metalls, or the like, I forthwith had recourse thereunto; where taking a just account of every observable Circumstance of the Earth, Stone, Metall, or other Matter, from the Surface quite down to the bottom of the Pit, I entered it carefully into a Journal, which I carry'd along with me for that purpose. . . . I likewise drew up a List of Quæries upon this Subject; which I dispatch'd into all Parts of the World, far and near, wherever either I myself, or any of my Acquaintance, had any Friend resident to transmit those Quæries unto. The Result of this was that in time I was abundantly assured that the Circumstances of these Things in remoter Countries were much the same with those of ours here: that the Stone, and other terrestrial Matter, in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into Strata, or Layers, as it is in England: that those Strata were divided by parallel Fissures: that there were enclosed in the Stone, and all the other denser kinds of terrestrial Matter, great numbers of Shells, and other Productions of the Sea; in the same manner as in that of this Island. To be short, by the same means I got sufficient intelligence that these Things were found in like manner in Barbary, in Egypt, in Guiney, and other parts of Africa: in Arabia, Syria, Persia, Malabar, China, and other Asiatick Provinces: in Jamaica, Barbadoes, Virginia, New-England, Brasil, Peru, and other parts of America.

This seems an amazing record of observations, paving the way, as it did, to the knowledge that the structure of the earth's surface was of like kind all the world over. It is important, however, to note that the author's collection bore no evidence of stratigraphical arrangement.

The shells and other marine bodies found on land "in the *deepest* bowels of the Earth, as well as upon the surface of it: upon the *tops* of even the *highest Hills and Mountains*, as well as in the *Valleys and Plains* . . . almost *everywhere*: in *all Countries and Quarters of the Globe*," were considered by John Woodward to have been originally generated and formed at sea—to be, in fact, "*the real spoils of once living Animals*."

Unfortunately, he insisted upon the universality of the Mosaic flood, maintaining that the "Terrestrial globe was taken all to pieces and dissolved at the deluge." He evidently meant the earth's crust as we now understand it, and that the terrestrial matter became disposed or settled down from the waters in layers, while the marine bodies were "lodged in those Strata according to the Order of their Gravity."

By his will, dated 1727, he founded the lectureship known as the Woodwardian Professorship in the University of Cambridge, and bequeathed to that seat of learning his collection of English fossils.

The lecturer was to be a bachelor, "lest the

care of a wife and children should take the lecturer too much from study and the care of the lecture"; and he was to read at least four lectures every year on some one or other of the subjects treated of in Woodward's *Natural History of the Earth* and other publications.

The first lecturer was appointed in 1731; but no systematic courses were given prior to 1818, when Sedgwick was chosen as Professor.¹ At that time the science of geology was looked upon as dangerous and suspicious; while another difficulty which confronted the new Professor was the decree of the founder that the lectures should be in conformity with his own theory, which amounted to this, as Sedgwick remarked: "That at the deluge the whole earth was melted down into a sort of Irish 'stirabout'"; but he "had given a liberal interpretation to his founder's will, and had endeavoured to adapt his teaching to the progressive state of the science."²

To the mathematician Leibnitz (1646-1716) we are indebted for the discrimination of aqueous and igneous rocks, in his *Protogæa*, published in 1680. That certain rocks had cooled from a state of fusion, and that others had been formed by diluvial action into more or less stratified masses, was the main portion of his

¹ *Life and Letters of Sedgwick*, by Clark and Hughes, vol. i., 1890, pp. 182, etc.

² *Geol. Mag.*, 1867, p. 45.

theory; but he concluded that, after the cooling of the crust, the vapours condensed into a universal ocean, and afterwards, when the crust became rent, the waters rushed into subterranean hollows, disrupting and ultimately depositing various stony and earthy strata. Had he not pictured the disturbances to have been violent and sudden, and the strata to have been tumultuously and rapidly deposited, his views would have been more in accordance with the modern doctrines of geology.

Among learned men several theologians began to take up the study of the earth's history, chiefly with the view of exhibiting proofs of the Mosaic deluge.

The Theory of the Earth, by the Rev. Thomas Burnet, Master of Charterhouse, issued in 1684, and his *Sacred Theory*, 1681-89; also *The New Theory of the Earth*, by William Whiston (1696), are works that have been since regarded as romantic and unprofitable labours. According to Burnet, the waters of the deluge issued from fissures in the earth's crust, the openings being caused by the heat of the sun's rays. Whiston attributed a certain portion of the waters to condensation of vapour from the tail of a comet; and had he lived to the present day he might have fortified his argument by quoting Sir Robert Ball, who, in lecturing on Halley's Comet, remarked that the tail might prove to be fifteen

million miles long. Some astronomers, indeed, have assigned a greater length to the tail. As remarked by Lyell: "Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptance, so that the doctrine of the earth having existed long previous to the creation of man might be no longer regarded as unorthodox." In this respect his views were sound.

If some of the ideas above expressed appear ridiculous, it is more astounding to find in 1909 an advocate of the "flat-earth theory."¹

Geology in the Eighteenth Century

Early in the eighteenth century the succession of strata in the Somerset coal district and other parts of England had attracted the attention of John Strachey, whose observations were published by the Royal Society in 1719 and 1725. He noted that the red earth (now known as Keuper Marl) rested horizontally on the inclined coal strata, and that above the red earth were beds of marl, limestone (Lias), freestone (Oolites), and chalk.

J. G. LEHMANN (-1767), who for a time taught mineralogy and mining in Berlin, in 1756 recognised the occurrence of primitive and non-

¹ *Daily Mail*, September 20, 1909.

fossiliferous rocks; also others of secondary origin, which were more or less fragmentary, and contained fossil remains, due to local or universal deluges. He described some of the rocks in Saxony, under the local names of Zechstein and Rothes Todtligendes (Rothliegende), now well-known divisions of the Permian.

Arduino (1713-1795), Professor of Mineralogy in Venice, further advanced knowledge by distinguishing, in 1759, a newer set of Tertiary strata that had characteristic fossils. He noted also the volcanic origin of the trap rocks.

In France, Rouelle (1703-1770), about the middle of the eighteenth century, observed the regular distribution of fossils in the Paris Basin. His views were disseminated in lectures; but he appears to have distinguished among the geological formations that there were, older and newer groups of strata, with an intermediate division, in which he placed the coal-formation.

Topographers and antiquaries in Britain did much to excite interest in the "formed-stones" or fossils. Thus the "snake-stones" (Ammonites) of Keynsham, and other prominent organic remains, were noticed by Leland in his itinerary, begun about 1538.

Specimens were collected for the purpose of forming grottoes. In this way Antonio Vallisneri gathered a number of fossil fishes from Monte Bolca, near Verona, and in 1721 pub-

lished descriptions of them. Eventually Agassiz described more than 130 species of fossil fishes from this famous locality, where, as Lyell has stated, they have been obtained from quarries in the fissile limestone, worked exclusively for the sake of the fossils.

To the great naturalist of Sweden, CARL LINNÆUS (1707-1778), who for a time practised medicine, we owe the immortal *Systema Naturæ*, the first edition of which was issued in 1735. Distinguished not only as botanist and zoölogist, he was one of the earliest to group minerals according to their crystalline forms. His main work, however, was his systematic classification of the different forms of life into genera and species, known as the binomial system; and he upheld the view that species have certain distinct and permanent characters which they have retained since their creation.

Modern palæontological nomenclature is based on the binomial system introduced in the tenth edition of the *Systema Naturæ* (1758-59). Names published by any author prior to January 1, 1758, are not recognised. Nevertheless, some names so published were re-published by the same or other authors at a later date; and, if properly supported by description, or figure, or both, are then valid, as if published for the first time.¹

¹ For these remarks on the present Rules of Nomenclature.

Buffon (1707-1788), who gave a theory of the earth in 1749 in his great work on Natural History, advocated the antiquity of the globe, and the great and gradual changes which its surface has undergone. Starting with a sphere surrounded by an ocean, he inferred, somewhat after the manner suggested by Leibnitz, that portions of water were transferred into subterranean cavities, whereby land appeared. He was impressed with the great destruction carried on by rivers and sea. As related by Lyell, his views were censured at the Sorbonne, then the Faculty of Theology in Paris, and Buffon made a declaration that he abandoned everything in his book respecting the formation of the earth that might be contrary to the narration of Moses.

Christopher Packe, M.D., published, in 1743, a *Chorographical Chart of East Kent*, which gave a good idea of the regular configuration of the hills and valleys and of the ranges of chalk, Kentish rag, and Weald clay. W. D. Conybeare spoke highly of this work, and of the instruction in field-geology which he gained from it.

To JEAN ETIENNE GUETTARD (1715-1786), also a doctor in medicine, we are indebted, in 1751, for a map and memoir on the distribution

ture the writer is indebted to Dr. F. L. Kitchin. There is, however, considerable difference of opinion with regard to the introduction of old names to replace those long in use and well known.

of minerals and rocks in France. This map, having different shadings and symbols to indicate the fossils and metals, as well as minerals and rocks, was one of the more important of the early geological maps. Later on, Guettard prepared a mineralogical map of Western Europe, and commenced a more detailed map of France, which was completed by Monnet and published in 1780. Guettard has been referred to as "the Father of all the National Geological Surveys" by Sir Archibald Geikie, who further observes that one of the most valuable parts of Guettard's work was his recognition of volcanic rocks, as in Central France, far removed from any active volcano.

Another French geologist, DESMARETS, in 1774 published further information on the former active volcanoes of the Auvergne, and instituted comparisons between the prismatic columns of basalt in that district and those of the Giant's Causeway, the origin of which had long perplexed observers.

Faujas St. Fond, in 1797, recognised the volcanic origin of the basalts in the Inner Hebrides.

William Stukeley, the antiquary, wrote on *The Philosophy of Earthquakes, Natural and Religious*, a work of which a third edition was published in 1756. His views, as noted by Sir A. Geikie, had been brought before the Royal

Society. He thought electricity was a cause of earthquakes; but from his descriptions of black, sulphurous clouds, and vapours that take fire, we are reminded of the spontaneous combustion that takes place along cliffs of shale which contains much pyrites. Such results often follow landslips; and landslips, as in the case of the great founder of Dowlands and Bindon, near Lyme Regis, which took place in 1839, have been attributed to earthquakes. In his *Itinerarium Curiosum* (1724), Stukeley recorded many notes on rocks and fossils observed by him in Great Britain.

In 1757, Emanuel Mendes da Costa published *A Natural History of Fossils*, a work of considerable interest, which deals with earths and stones, but not with the "figured bodies," or true fossils.

In 1766, Gustavus Brander (1720–1787), a London merchant, published a work on Hampshire fossils—*Fossilia Hantoniensia*—in which were figured many Tertiary mollusca collected from the fossiliferous clays at Barton and Hordwell. The species were described by Solander, then an officer in the British Museum, and so accurately were they represented on the plates that they can be readily identified now. Brander recognised that the forms were such as lived in warmer regions.

J. T. Klein had published in 1734 a work on fossil Echinodermata, and a new edition of this

volume was published at Leipzig in 1778, under the editorship of N. G. Leske, and entitled *Naturalis dispositio Echinodermatum*. To Leske we owe the names of the familiar chalk sea-urchins *Echinocorys scutatus* (better known as *Ananchytes ovatus*) and *Conulus* (or *Galerites*) *albogalerus*. According to the Rules of Nomenclature, previously noted, the original names of Klein would only be perpetuated on the authority of Leske.

The Rev. JOHN MICHELL, Woodwardian Professor at Cambridge, in 1760 published observations on Earthquakes. In the course of his remarks he described the disturbances and fractures of the strata, of which he evidently had a good general knowledge, inasmuch as he noted the mountainous ridges of the old rocks, or "lower strata of earth," and the bordering belts of regular and uniform strata. He was likewise acquainted, about the year 1788, with the general sequence of strata from the coal-measures to the chalk; and it has been remarked that "a foremost place may be claimed for him among the founders of modern geology."¹

FÜCHSEL (1723-1773), in Germany, published in 1762, and afterwards, accounts of the succession of strata and of the fossils, marine shells, and land-plants found in the Thuringer Wald

¹ *Life and Letters of Sedgwick*, by Clark and Hughes, vol. i. (1890), p. 192.

and other areas. He observed that the rocks, now known as Permian and Trias, were disturbed from their original position, and, as far as possible, he explained the phenomena by reference to modern agencies.

H. B. DE SAUSSURE (1740-1799), distinguished for his early studies of the rocks and physical features of Switzerland, in his *Voyages dans les Alpes* (1779-96), called attention to the evidences of great disturbance in strata that must have been formed horizontally, recognised that there might be a succession in the appearance of different fossils, and was struck by the evidence of erosion by rain and rivers. As noted by Sir A. Geikie (1905), he made "a series of experiments in fusion, in order to determine for himself the probable origin of different rocks, and especially to enable him to decide whether certain varieties could be produced by the melting of others."

J. A. DE LUC (1727-1817), a great traveller, was a careful and shrewd observer of the physical changes now going on, and to him we owe the scientific use of the term "Geology," which he introduced casually in 1778, and more definitely in subsequent works. He was author of a volume on the principles and facts concerning Cosmology and Geology (1803), and of an elementary treatise on Geology (1809), as well as of geological travels. Townsend, in 1813.

remarked that to him "Geology is indebted for more numerous facts than have ever been presented to the world before he brought them forward to our view."

In the later years of the eighteenth century and for some time afterwards every parish had, if possible, its pit or quarry for road-stone; and the heaps of broken rock or gravel often contained fossils which attracted the attention of the pedestrian and the traveller by coach or post-chaise. Among such specimens were the snake-stones (*Ammonites*), thunderbolts (*Bellemnites*), devil's toenails (*Gryphæa*), Pundibs (*Terebratula*), and poundstones or quoitstones (*Clypeus*), which, according to William Smith, were used as pound-weights by dairywomen. There were also Bufonites or toad-stones (palatal teeth of fishes), and many other specimens to which popular names were given, especially among the chalk fossils. Collectors, or "fossilists," became interested, some for purposes of trade, others out of curiosity and as amateurs.

W. G. Maton, in his *Observations on the Western Counties of England* (made in 1794 and 1796), remarks of Charmouth, near Lyme Regis, that

The cliffs, which are chiefly composed of indurated marl, abound with *madreporæ*, *am-*

monitæ, *belemnitæ*, and skeletons of fishes and other animals in a fossil state. The *ludus helmontii* [septarium] is common here, and it is difficult to persuade the vulgar that it is not a *fossil turtle*. All curious productions of this nature are diligently collected by a man living at Charmouth, who is generally known throughout the county by the name of the *Curi-man*.¹

Further reference will be made to this celebrated district.

Fossils were sometimes used for medical and other purposes. The Gryphæas of the Lower Lias, so abundant in Gloucestershire, as at Fretherne and Awre, were ground to a powder, mixed with whey, and used as a medicine for cattle. In the same county Belemnites were reduced to a powder, which was used to cure watery affections of the eyes of horses. In Scotland the Gryphæa, abundant in parts of the Inner Hebrides, was valued as an amulet and a cure for pains in the joints. Belemnites from the Oxford clay of Bedfordshire and Buckinghamshire have also been employed as a medicine for sore eyes and for rheumatism. In Texas, Lower Cretaceous Gryphæas are so abundant that in recent years they have been used for road-metal and burnt for lime.

¹ Vol. i., 1797, p. 75.

On the Continent, as in Britain, there were many collectors of fossils.

Maestricht has long been celebrated for its extensive quarries in yellow and somewhat arenaceous limestone, a freestone about fifty feet thick, in the higher part of the Cretaceous series, overlying white chalk with flints. About the year 1766 remains of a "large fossil animal" were brought to notice from the freestone, and in 1770 the workmen obtained near Fort St. Peter, on the eminence known as St. Peter's Mountain, part of an enormous head. Information of this discovery was given to Hoffman, who was surgeon of the fort, and he, being an enthusiastic collector of fossils, laboured with unflagging zeal and energy until the remains were extracted. Great interest was manifested in the discovery, so much so that the Canon of the Cathedral, as recorded by Faujas St. Fond, resolved to claim the fossil as proprietor of the land beneath which it had been found. Hoffman defended his right in a court of justice, but the verdict was against him, and he had not only to part with his fossil, but to pay heavy legal expenses. Years afterwards, when Hoffman had died and the French Revolution had broken out, the armies of the Republic in 1794 advanced to the gates of Maestricht, and it is recorded that "The town was bombarded; but, at the suggestion of the committee of savants who

accompanied the French troops to select their share of the plunder, the artillery was not suffered to play on that part of the city in which the celebrated fossil was known to be preserved." When the city was taken, the French authorities gained possession of the fossil prize, and sent it to the Jardin des Plantes at Paris.* Much difficulty arose in the determination of the animal, but it was ascertained not to belong to "physeter, fish, nor crocodile." The genus of the fossil reptile of Maestricht was ultimately named *Mosasaurus*, or the Lizard of the Meuse, by W. D. Conybeare, in 1824; and the species preserved in the Paris Museum was named *M. Camperi* by Cuvier. The estimated length of the reptile was twenty-five feet. It has since been ascertained that the Mosasaurians, which were swimming reptiles, had a wide range during the Cretaceous period; and representatives of the family have been found in Kansas, in the United States, and in New Zealand, as well as in England.

Among the more remarkable discoveries in the latter part of the eighteenth century was that made in 1772 by Pallas, who found the carcass of an extinct rhinoceros in the frozen sand on

* For the above particulars the writer is indebted to Parkinson's *Organic Remains*, ed. ii., vol. iii., 1833, p. 298, and Mantell's *Petrifactions and their Teachings*, 1851, p. 194.

the banks of a tributary of the Lena in Siberia, the skin being covered with short wool and hair. Hence the animal came to be described as the woolly rhinoceros, and it is known as *Rhinoceros tichorhinus* or *antiquitatis*.

In 1803 the entire carcass of a mammoth was found in ice by Adams, further north on the banks of the Lena, the flesh being well preserved, and the skin, like that of the rhinoceros, being covered with wool and hair. Sir H. H. Howorth has pointed out, however, that the existence of mammoth remains with the flesh preserved had been known in the latter part of the seventeenth century.¹

These remains, as recorded by Lyell,² are found in the more elevated lands between the great rivers, and are brought to light at torrential times, when the rivers cut out fresh channels. As the soil is always frozen to within a slight depth of the surface, it is evident that the ice or congealed mud in which the bodies were enveloped has remained in that condition since the animals perished.

Other discoveries of more or less complete remains have since been made. The occurrence of bones had been known for long periods, and great quantities of the fossil tusks of the ele-

¹ *Geol. Mag.*, 1880, p. 492; and *The Mammoth and the Flood*, 1887.

² *Principles*, ed. xi., 1872, vol. i., pp. 179, etc.

phant had been gathered for ivory. Thus, in 1821, it was estimated that 20,000 lbs. of fossil ivory were procured from the island of New Siberia.¹ The significance of the facts was recognised about twenty years later by Agassiz.

¹ See *The Polar Regions*, by Sir John Richardson (1861), pp. 294, 295.

CHAPTER II

THE FOUNDERS OF GEOLOGY AS A SCIENCE

THE last quarter of the eighteenth century witnessed the birth of geology as a science; and it is interesting to learn that H. B. de Saussure had adopted the term "geology" almost as soon as De Luc, and in 1779 alluded "to the geologist as if he were a well-known species of natural philosopher."¹

Whewell described the previous long ages of geological speculation as "The Fabulous Period"; but it was a period characterised by the record of facts, and often sagacious observations and interpretations mingled with crude and absurd hypotheses.

The period from 1790 to 1820 Zittel characterised as "The Heroic Age of Geology." It was a momentous period, during which the foundations of the true science of geology were laid by Werner, Hutton, and William Smith, and consolidated by Lamarck and Cuvier.

¹ Sir A. Geikie (1905).

Founders of Geology as a Science 33

WERNER (1749-1817), who was born in Saxony, was the son of a mining inspector, and early in youth began to collect minerals and rocks. Ultimately, as Professor of Mining at Freiberg, he became a great and enthusiastic teacher, not only of mining, but also of mineralogy and geognosy—the last-named term being practically equivalent to geology, and implying a knowledge of the earth.

Although author of several works, notably the *Kürze Klassifikation* (1787), the views of Werner were propagated mainly through his pupils, and his great work was that of training geological observers. Despite the errors of a part of his teaching, "his eloquence and inspiration affected mighty services for geology" (as remarked by Edward Forbes), through the love for the science with which his disciples became imbued. To him we owe much of our earlier knowledge of the Primitive formations, which included granite, gneiss, mica slate, clay slate, etc. Next in succession was a group termed Transition formations, being an intermediate series resting on highly-inclined rocks, and equivalent to strata, now classed as Palæozoic, from the older and conspicuously fossiliferous rocks to the Lower Carboniferous. Above came the Floetz (or Secondary) groups of Werner, so called because well stratified, and usually flat or horizontal; the main group includ-

ing the Coal-measures and other Secondary strata, while the Newest Floetz class was the term applied to the Tertiary deposits.

Werner taught that the organic remains found in the different rocks, in upward succession from the Transition strata, bore a constant relation to the age of the deposits. To these he applied the name "formations," about the year 1790 or 1791. His descriptions of the strata were, however, mostly mineralogical, and the distinctive feature of his teaching was that all rocks above the Primitive were of aqueous deposition, including the trap rocks, since universally acknowledged to be of igneous origin. Hence arose the school of Neptunists.

A further serious defect in Werner's teaching arose from his limited knowledge of the extent of geological formations; he framed his theories from the succession known to him, and took it as a type for that of the earth in general. Volcanoes originated, in his opinion, from the combustion of underground seams of coal.

He adopted names in practical use among quarrymen and miners, such as gneiss, grau-wacke (or greywacke), muschelkalk, gryphite-limestone, as well as other names, such as rothe-todte-liegende and zechstein, that had previously been introduced into scientific publications.

In mineralogy Werner advanced knowledge

with respect to the external characters, such as the colour, lustre, hardness, and specific gravity of minerals.

JAMES HUTTON, M.D. (1726-1797), although educated for the medical profession, did not practise, and was mainly occupied in agricultural pursuits. In 1785 he communicated to the Royal Society of Edinburgh his famous "Theory of the Earth; or, an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe."

His views were based on the examination and study of the "natural operations of the globe." He saw in the deposits of sand, gravel, clay, and limestone, the results of the deposition of sediment, together with organic remains, under water, whether of river or sea; and he recognised that the greater part of the solid land had been beneath the ocean. He discussed the consolidation of strata, and then dealt with the problems of upheaval. The fact was noted that, while the strata must have been deposited in a position horizontal, or nearly so, now they are found in every possible position, broken and separated, bent and doubled. The questions of elevation due to extreme heat and expansion, and the disturbances connected with volcanoes and earthquakes, were considered; and it was remarked that "these operations of the globe

remain at present with undiminished activity, or in the fulness of their power." Regarding the changes in the crust as largely due to the energy of fire, the followers of Hutton came to be known as Vulcanists or Plutonists.

He called attention to the various forms of trap rocks, so named by Swedish observers, and recognised the intrusive nature of the whinstone of Scotland, and the ragstone (Rowley Rag) of South Staffordshire. He made comparisons between them and the lavas that had issued from a volcano, remarking that Dolomieu had observed the distinction "without seeming to know the principle upon which this essential difference depends." Hutton's conclusions are clearly expressed:

There can be no doubt that these two different species of bodies have had the same origin, and that they are composed of the same materials nearly; but from the different circumstances of their production, there is formed a character to these bodies, by which they may be perfectly distinguished. The difference of those circumstances consists in this: the one has been emitted to the atmosphere in its fluid state, the other only came to be exposed to the light in a long course of time, after it had congealed under the compression of an immense load of earth, and after certain operations, proper to the mineral regions, had been exercised upon the indurated mass.

It is interesting to find that Hutton realised, as John Woodward had ascertained, that "the great masses of the earth are the same everywhere"; but he further remarked that "all the different species of earths, of rocks or stone, which have as yet appeared, are to be found in the little space of this our island," with some exceptions in the "peculiar productions in the mineral kingdom," such as the diamond.

In considering the *System of Decay and Renovation Observed in the Earth*, Hutton saw no occasion to have recourse "to the agency of any preternatural cause, in explaining that which actually appears." As he observed, "the destruction of one continent is not brought about without the renovation of the earth in the production of another." Rivers in flood and storms upon the coast were cited as witnesses of destruction—that "the land is perishing continually." Parts of the earth might sink, other parts were raised; and, while there was a system in the changes continually in operation, he remarked: "The result, therefore, of our present inquiry is, that we find no vestige of a beginning,—no prospect of an end."

Hutton has been justly regarded as the founder of modern geology, inasmuch as he appealed to the ordinary operation of actual causes, and thus established the true principles of the science. His *Theory of the Earth, with Proofs and*

Illustrations, was issued in two volumes (1795), the original essay being reprinted, with slight additions, in the first volume, together with new material in that and in the second volume.

In 1802 John Playfair (1748–1819), Professor of Mathematics in the University of Edinburgh, issued a volume entitled *Illustrations of the Huttonian Theory of the Earth*, with the view of explaining the theory of Hutton “in a manner more popular and perspicuous than is done in his own writings.”

A third volume, portions of an incomplete MS. of the *Theory of the Earth*, was published by the Geological Society of London in 1899, under the editorship of Sir Archibald Geikie. In it are given Hutton’s views regarding the origin of granite; and of especial interest is the record of his observations at Glen Tilt, where he found the granite “interjected in every possible direction among the strata which appear”—various schists and limestone. Hutton was thus able to demonstrate the igneous origin of granite, and the fact of its protrusion through strata previously formed. He likewise noted the alteration produced by the heat.

His observations on the effects of erosion in producing the diversity of scenery have perhaps had the greatest influence on modern geology.

The effects produced by streams and rivers on the erosion of the land and the encroachment of the sea had been observed by the earliest philosophers, and the subject was dealt with by many subsequent writers, notably by the naturalist Ray in 1692. Others, however, like Catcott, who in 1761 wrote on the universality of the deluge, attributed much of the erosion to the action of the diluvial currents. Modified views on the subject, as noted in the sequel, are held now; for it is manifest that many streams, in their present condition, are not powerful enough to transport the coarse gravelly detritus that borders their channels.

Playfair was thoroughly acquainted with all the views of Hutton, whom he had accompanied on many excursions; and he was thus able to amplify our knowledge of his doctrines. As Sir A. Geikie has remarked, the extraordinary merit of the new volume of *Illustrations* was at once recognised:

In Playfair's glowing pages the excellences and the defects of his master's system are faithfully reflected. Never before had so eloquent and convincing a sketch been given of the co-operation of underground and superficial agencies in the decay and renovation of land, and in the perpetuation of the conditions that make this planet a habitable globe. No previous writer had set in so

clear a light the sculpture of the land by the flow of rain and rivers across its surface.¹

For some years much controversy arose between the disciples of Werner and Hutton—the Neptunists and Vulcanists.

In Edinburgh Robert Jameson (1774–1854), Professor of Natural History from 1804 and during fifty years, for long upheld the doctrines of Werner and founded a Wernerian Society, but was ultimately converted to the views of Hutton. In Ireland Richard Kirwan supported the Wernerian views in his *Geological Essays*, published in 1799. Ami Boué, a pupil of Jameson, however, became a strong opponent of the views of Werner; and Von Buch, a pupil of Werner, soon came to discern the igneous origin of the trap rocks.

The doctrines of Hutton were strongly supported by Sir JAMES HALL, of Dunglass, who has been regarded as the founder of experimental geology, although, as already noted, De Saussure had anticipated the advantage to be gained by research of this kind.

Hall's experiments on the fusion of whinstone showed that when rapidly cooled, the rock became glassy, and when slowly cooled the texture became stony and more or less crystalline.

¹ "Lamarck and Playfair: A Geological Retrospect of the Year 1902." *Geol. Mag.*, 1906, p. 198.

Important, too, was his experiment on the heating under pressure of powdered chalk, whereby, instead of becoming caustic lime by the loss of carbonic acid, it was converted into a crystalline rock resembling marble. Examples of such alteration are met with in the Durness limestone of Strath, Skye, and in the Carrara marble. Hall travelled a good deal, and was an acute observer, giving a sound and original account of the formation of volcanic dykes and cones, and pointing out (as Murchison recorded) "that Monte Somma was simply the segment of a vast volcano, from the flank of which the present Vesuvius had arisen."

The experiments on rocks initiated by Hall and carried out by him during the years 1790 to 1825 were followed at later periods in more detail by Daubrée, C. J. St. Claire-Deville, Delesse, and Fouqué.¹

The teachings of Werner and Hutton were mainly concerned with the stratified and unstratified formations, their origin and relations, and with the physical changes now in progress; and, as remarked by Lyell, while the tenets of the rival schools of Freiberg and Edinburgh were warmly espoused by devoted partisans, "the labours of an individual, unassisted by the

¹ See Rudler (1889).

CHAPTER II

THE FOUNDERS OF GEOLOGY AS A SCIENCE

THE last quarter of the eighteenth century witnessed the birth of geology as a science; and it is interesting to learn that H. B. de Saussure had adopted the term "geology" almost as soon as De Luc, and in 1779 alluded "to the geologist as if he were a well-known species of natural philosopher."^{*}

Whewell described the previous long ages of geological speculation as "The Fabulous Period"; but it was a period characterised by the record of facts, and often sagacious observations and interpretations mingled with crude and absurd hypotheses.

The period from 1790 to 1820 Zittel characterised as "The Heroic Age of Geology." It was a momentous period, during which the foundations of the true science of geology were laid by Werner, Hutton, and William Smith, and consolidated by Lamarck and Cuvier.

^{*} Sir A. Geikie (1905).

Founders of Geology as a Science 33

WERNER (1749–1817), who was born in Saxony, was the son of a mining inspector, and early in youth began to collect minerals and rocks. Ultimately, as Professor of Mining at Freiberg, he became a great and enthusiastic teacher, not only of mining, but also of mineralogy and geognosy—the last-named term being practically equivalent to geology, and implying a knowledge of the earth.

Although author of several works, notably the *Kürze Klassifikation* (1787), the views of Werner were propagated mainly through his pupils, and his great work was that of training geological observers. Despite the errors of a part of his teaching, “his eloquence and inspiration affected mighty services for geology” (as remarked by Edward Forbes), through the love for the science with which his disciples became imbued. To him we owe much of our earlier knowledge of the Primitive formations, which included granite, gneiss, mica slate, clay slate, etc. Next in succession was a group termed Transition formations, being an intermediate series resting on highly-inclined rocks, and equivalent to strata, now classed as Palæozoic, from the older and conspicuously fossiliferous rocks to the Lower Carboniferous. Above came the Floetz (or Secondary) groups of Werner, so called because well stratified, and usually flat or horizontal; the main group includ-

ing the Coal-measures and other Secondary strata, while the Newest Floetz class was the term applied to the Tertiary deposits.

Werner taught that the organic remains found in the different rocks, in upward succession from the Transition strata, bore a constant relation to the age of the deposits. To these he applied the name "formations," about the year 1790 or 1791. His descriptions of the strata were, however, mostly mineralogical, and the distinctive feature of his teaching was that all rocks above the Primitive were of aqueous deposition, including the trap rocks, since universally acknowledged to be of igneous origin. Hence arose the school of Neptunists.

A further serious defect in Werner's teaching arose from his limited knowledge of the extent of geological formations; he framed his theories from the succession known to him, and took it as a type for that of the earth in general. Volcanoes originated, in his opinion, from the combustion of underground seams of coal.

He adopted names in practical use among quarrymen and miners, such as gneiss, grauwacke (or greywacke), muschelkalk, gryphite-limestone, as well as other names, such as rothe-todte-liegende and zechstein, that had previously been introduced into scientific publications.

In mineralogy Werner advanced knowledge

with respect to the external characters, such as the colour, lustre, hardness, and specific gravity of minerals.

JAMES HUTTON, M.D. (1726-1797), although educated for the medical profession, did not practise, and was mainly occupied in agricultural pursuits. In 1785 he communicated to the Royal Society of Edinburgh his famous "Theory of the Earth; or, an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe."

His views were based on the examination and study of the "natural operations of the globe." He saw in the deposits of sand, gravel, clay, and limestone, the results of the deposition of sediment, together with organic remains, under water, whether of river or sea; and he recognised that the greater part of the solid land had been beneath the ocean. He discussed the consolidation of strata, and then dealt with the problems of upheaval. The fact was noted that, while the strata must have been deposited in a position horizontal, or nearly so, now they are found in every possible position, broken and separated, bent and doubled. The questions of elevation due to extreme heat and expansion, and the disturbances connected with volcanoes and earthquakes, were considered; and it was remarked that "these operations of the globe

remain at present with undiminished activity, or in the fulness of their power." Regarding the changes in the crust as largely due to the energy of fire, the followers of Hutton came to be known as Vulcanists or Plutonists.

He called attention to the various forms of trap rocks, so named by Swedish observers, and recognised the intrusive nature of the whinstone of Scotland, and the ragstone (Rowley Rag) of South Staffordshire. He made comparisons between them and the lavas that had issued from a volcano, remarking that Dolomieu had observed the distinction "without seeming to know the principle upon which this essential difference depends." Hutton's conclusions are clearly expressed:

There can be no doubt that these two different species of bodies have had the same origin, and that they are composed of the same materials nearly; but from the different circumstances of their production, there is formed a character to these bodies, by which they may be perfectly distinguished. The difference of those circumstances consists in this: the one has been emitted to the atmosphere in its fluid state, the other only came to be exposed to the light in a long course of time, after it had congealed under the compression of an immense load of earth, and after certain operations, proper to the mineral regions, had been exercised upon the indurated mass.

It is interesting to find that Hutton realised, as John Woodward had ascertained, that "the great masses of the earth are the same everywhere"; but he further remarked that "all the different species of earths, of rocks or stone, which have as yet appeared, are to be found in the little space of this our island," with some exceptions in the "peculiar productions in the mineral kingdom," such as the diamond.

In considering the *System of Decay and Renovation Observed in the Earth*, Hutton saw no occasion to have recourse "to the agency of any preternatural cause, in explaining that which actually appears." As he observed, "the destruction of one continent is not brought about without the renovation of the earth in the production of another." Rivers in flood and storms upon the coast were cited as witnesses of destruction—that "the land is perishing continually." Parts of the earth might sink, other parts were raised; and, while there was a system in the changes continually in operation, he remarked: "The result, therefore, of our present inquiry is, that we find no vestige of a beginning,—no prospect of an end."

Hutton has been justly regarded as the founder of modern geology, inasmuch as he appealed to the ordinary operation of actual causes, and thus established the true principles of the science. His *Theory of the Earth, with Proofs and*

Illustrations, was issued in two volumes (1795), the original essay being reprinted, with slight additions, in the first volume, together with new material in that and in the second volume.

In 1802 John Playfair (1748–1819), Professor of Mathematics in the University of Edinburgh, issued a volume entitled *Illustrations of the Huttonian Theory of the Earth*, with the view of explaining the theory of Hutton “in a manner more popular and perspicuous than is done in his own writings.”

A third volume, portions of an incomplete MS. of the *Theory of the Earth*, was published by the Geological Society of London in 1899, under the editorship of Sir Archibald Geikie. In it are given Hutton's views regarding the origin of granite; and of especial interest is the record of his observations at Glen Tilt, where he found the granite “interjected in every possible direction among the strata which appear”—various schists and limestone. Hutton was thus able to demonstrate the igneous origin of granite, and the fact of its protrusion through strata previously formed. He likewise noted the alteration produced by the heat.

His observations on the effects of erosion in producing the diversity of scenery have perhaps had the greatest influence on modern geology.

The effects produced by streams and rivers on the erosion of the land and the encroachment of the sea had been observed by the earliest philosophers, and the subject was dealt with by many subsequent writers, notably by the naturalist Ray in 1692. Others, however, like Catcott, who in 1761 wrote on the universality of the deluge, attributed much of the erosion to the action of the diluvial currents. Modified views on the subject, as noted in the sequel, are held now; for it is manifest that many streams, in their present condition, are not powerful enough to transport the coarse gravelly detritus that borders their channels.

Playfair was thoroughly acquainted with all the views of Hutton, whom he had accompanied on many excursions; and he was thus able to amplify our knowledge of his doctrines. As Sir A. Geikie has remarked, the extraordinary merit of the new volume of *Illustrations* was at once recognised:

In Playfair's glowing pages the excellences and the defects of his master's system are faithfully reflected. Never before had so eloquent and convincing a sketch been given of the co-operation of underground and superficial agencies in the decay and renovation of land, and in the perpetuation of the conditions that make this planet a habitable globe. No previous writer had set in so

clear a light the sculpture of the land by the flow of rain and rivers across its surface.¹

For some years much controversy arose between the disciples of Werner and Hutton—the Neptunists and Vulcanists.

In Edinburgh Robert Jameson (1774–1854), Professor of Natural History from 1804 and during fifty years, for long upheld the doctrines of Werner and founded a Wernerian Society, but was ultimately converted to the views of Hutton. In Ireland Richard Kirwan supported the Wernerian views in his *Geological Essays*, published in 1799. Ami Boué, a pupil of Jameson, however, became a strong opponent of the views of Werner; and Von Buch, a pupil of Werner, soon came to discern the igneous origin of the trap rocks.

The doctrines of Hutton were strongly supported by Sir JAMES HALL, of Dunglass, who has been regarded as the founder of experimental geology, although, as already noted, De Saussure had anticipated the advantage to be gained by research of this kind.

Hall's experiments on the fusion of whinstone showed that when rapidly cooled, the rock became glassy, and when slowly cooled the texture became stony and more or less crystalline.

¹ "Lamarck and Playfair: A Geological Retrospect of the Year 1902." *Geol. Mag.*, 1906, p. 198.

Important, too, was his experiment on the heating under pressure of powdered chalk, whereby, instead of becoming caustic lime by the loss of carbonic acid, it was converted into a crystalline rock resembling marble. Examples of such alteration are met with in the Durness limestone of Strath, Skye, and in the Carrara marble. Hall travelled a good deal, and was an acute observer, giving a sound and original account of the formation of volcanic dykes and cones, and pointing out (as Murchison recorded) "that Monte Somma was simply the segment of a vast volcano, from the flank of which the present Vesuvius had arisen."

The experiments on rocks initiated by Hall and carried out by him during the years 1790 to 1825 were followed at later periods in more detail by Daubrée, C. J. St. Claire-Deville, Delesse, and Fouqué.¹

The teachings of Werner and Hutton were mainly concerned with the stratified and unstratified formations, their origin and relations, and with the physical changes now in progress; and, as remarked by Lyell, while the tenets of the rival schools of Freiberg and Edinburgh were warmly espoused by devoted partisans, "the labours of an individual, unassisted by the

¹ See Rudler (1889).

advantages of wealth or station in society, were almost unheeded."

In the village of Churchill, near Chipping Norton in Oxfordshire, there was born WILLIAM SMITH (1769-1839), who, as designated by Sedgwick in 1831, is the recognised "Father of English Geology." The son of a mechanic, who died when the child was but eight years old, William Smith was assisted by an uncle, a practical farmer, from whom he learnt processes of draining and improving land, while he taught himself the rudiments of geometry and surveying. Thus, when a youth of eighteen, he was qualified to become assistant to a surveyor at Stow-on-the-Wold, and for about six years was engaged in various surveys in the west of England. In the course of this work he became interested in the different soils and strata, and ultimately described himself as a "mineral surveyor." In 1793 he had ascertained from his own observations the succession in East Somerset, above the more highly inclined coal-measures, of the red ground, lias, and freestone which had a gentle inclination eastwards: not knowing that the order of these formations had been noted by Strachey in the early part of the century. Later on, a tour from Bath to Newcastle and back enabled Smith to make general observations on the great ranges of strata, which, as he discerned, follow to a certain extent the



WILLIAM SMITH.
From an engraving by T. A. Dean.

contours and other features—so that he came to recognise the extensions of the freestones (Oolites) and chalk of the west of England in the moors and wolds of Eastern Yorkshire. He noticed the wide extent also of the red rocks, saw the magnesian limestone which was unknown in the south, and also the (Carboniferous) limestone rocks of Matlock.

Subsequently he learnt much more of the detailed structure of East Somerset while engaged for six years in planning and superintending the works for the Somerset Coal Canal. As recorded by his nephew, John Phillips, he found peculiar plants in the coal-strata, no fossils in the Red ground, but many particular shells in the Lias and Freestones. In 1795 he had made his first stratigraphical collection; and the result was that in 1796 he realised how (in most cases) "each stratum contained organised fossils peculiar to itself," and by which it could be identified.¹ As Smith himself relates, "the first written account of this discovery was circulated in 1799." That his most important and far-reaching observations were "entirely original" is unquestioned; and that they were "unincumbered with theories" was no doubt owing to his meagre knowledge of English scientific works, and to the fact that

¹ See W. S. Mitchell, *Geol. Mag.*, 1869, p. 358.

he was unacquainted with foreign literature. He was aided in the naming of his fossils by the Rev. Benjamin Richardson, Rector of Farleigh, Hungerford, who had a fine museum of local organic remains; but it is noteworthy that Smith, on viewing the collection, surprised Richardson by describing the particular strata or formations to which the many specimens belonged.

The fact of the identification of strata by their fossils was communicated to the Rev. Joseph Townsend, Rector of Pewsey, and he, like Richardson, was greatly impressed with the novelty and importance of it. He "declared it perfectly unknown to all his acquaintance," and he had pursued researches on the strata and on mineralogy for forty or fifty years, travelling much in Europe, and meeting many distinguished men of science. After a dinner at the house of Mr. Townsend (then resident in Bath) when Richardson and Smith were present, the Table of Strata of 1799 was drawn up by Richardson from Smith's dictation; and, in accordance with Smith's desire, copies of it were distributed without reserve, abroad as well as at home.¹ Some years elapsed, however, before the great discovery of Smith became generally known and its important applications were realised.

¹ *Proc. Geol. Soc.*, i., p. 276.

In 1815 Smith, after many difficulties and delays, published his *Geological Map of England and Wales, with Part of Scotland*, on the scale of an inch to five miles, in fifteen sheets. This great work, the result of twenty years' original observation, did more at the time to establish the fame of the author than his discovery of the sequence of organic remains.

Smith also, during the years 1819 to 1824, issued twenty-one county geological maps of England, and several geological sections, the result of personal observations made during many journeys, and with the advantage in those days of noting, as he did, from the top of a coach, the physical features and their relation to the geological structure.

The following table will be of interest in showing the principal dates of the nomenclature and succession of formations according to William Smith:

SMITH'S MS., DRAWN UP IN 1799.	SMITH'S TABLES, DRAWN UP IN 1815 AND 1816, AFTER FIRST COPIES OF MAP HAD BEEN ISSUED; PUBLISHED IN 1817.	PRESENT GROUPING, 1910.
	London Clay. Clay or Brickearth, with interspersions of Sand and Gravel.	In part Woolwich and Reading Beds; in part Thames Valley deposits.
	Crag. Sand and light Loam.	In part Thanet, Wool- wich, and Reading Beds; in part Crag above London Clay.

Founders of Geology as a Science 47

SMITH'S MS., DRAWN UP IN 1799.	SMITH'S TABLES, DRAWN UP IN 1815 AND 1816, AFTER FIRST COPIES OF MAP HAD BEEN ISSUED: PUBLISHED IN 1817.	PRESENT GROUPING, 1910.
Chalk.	Chalk } Upper with flints; } Lower with no } flints.	Chalk.
Sand.	Green Sand. Brickearth; Blue Marl. Sand, Purbeck Stone, Kentish Rag. Portland Rock. Sand. Oaktree Clay. Coral Rag and Pisolite; Iron Sand and Carstone; Sand.	Upper Greensand. Gault. Lower Greensand and Purbeck Beds.
Clay.	Clunch Clay and Shale. Kellaways Stone. Cornbrash.	{ Portland Beds. Kimeridge Clay. { Corallian (Iron Sand { and Carstone, Lower { Greensand). Oxford Clay. Kellaways Rock. Cornbrash.
Sand and Stone. Clay. Forest Marble.	{ Sand and Sandstone. Forest Marble.	{ Forest Marble.
Freestone. Blue Clay. Yellow Clay. Fuller's Earth, etc.	Clay over Upper Oolite. Upper Oolite.	Bradford Clay. Great Oolite.
Freestone. Sand.	{ Fuller's Earth and Rock.	Fuller's Earth and Rock.
Marl Blue. Lias Blue. White Lias. Marl Stone. Indigo and Black Marl.	Under Oolite. Sand. Marlstone. Blue Marl. Blue Lias. White Lias.	Inferior Oolite. Midford Sand. Middle Lias. { Middle and Lower { Lias.
Red-ground. Millstone.	Red Marl.	{ Rhætic Beds.
	Redland Limestone, Magnesian Limestone, Soft Sandstone.	Keuper. Dolomitic Conglomerate. Magnesian Limestone Series.
Pennant Street. Grays. Cliff. Coal.	{ Coal Measures.	Coal Measures.
	Mountain Limestone.	Carboniferous Limestone.

SMITH'S MS., DRAWN UP IN 1799.	SMITH'S TABLES, DRAWN UP IN 1815 AND 1816, AFTER FIRST COPIES OF MAP HAD BEEN ISSUED: PUBLISHED IN 1817.	PRESENT GROUPING, 1910.
	Red Rhab and Dun- stone; Killas or Slate. Granite, Sienite, and Gneiss.	Old Red Sandstone, Devonian, and older Palæozoic. Igneous and Meta- morphic.

In Smith's later table, it will be noticed that the position of the Crag was misplaced, and that the strata above the London clay were not sufficiently known. He observed that the shells near the bottom of the London clay were difficult to be distinguished from those of the Crag; and it is noteworthy that this fact puzzled later observers when the fossils of the Lenham Beds were discovered. Perplexity arose, no doubt, from the various superficial deposits of loam, sand, gravel, etc. Lower greensand had not been defined, and was confused in part with the Upper greensand, in part with Corallian; the Wealden Beds were not recognised, the Weald clay being doubtfully classed as Oaktree clay. The Upper Lias clay above the Marlstone, being poorly exposed in Somerset, was not defined.

The Forest Marble, much used for roofing-purposes, was wrongly identified at Stunsfield or Stonesfield, where stone tiles have long been obtained.

William Smith, in the Introduction to his *Strata Identified by Organised Fossils*, the first part of which was published in 1816, remarked that

the organised Fossils (which might be called the antiquities of Nature), and their localities also, may be understood by all, even the most illiterate: for they are so fixed in the earth as not to be mistaken or misplaced; and may be as readily referred to in any part of the course of the Stratum which contains them, as in the cabinets of the curious; and, consequently, they furnish the best of all clues to a knowledge of the Soil and Substrata.

It was the fossils which first enabled Smith "more particularly to distinguish one Stratum from another." This may be readily understood when we find certain formations, like the Great Oolite and the Inferior Oolite, presenting in the same district somewhat similar lithological characters; and this is the case also with the beds of Lias clay, Fuller's-earth clay, Oxford clay, and Kimeridge clay.

The method of Smith was to arrange "fossils generally, according to the strata which contain them." The geological formations, which he described and named, were defined by their lithological and stratigraphical characters, and the fauna as a whole was indicated. Smith did not realise that the several formations were the

more or less local phases of sedimentation. Long-continued and detailed research over large areas could alone prove that each marine formation represented but a portion of the seabed of the time, and that sands, clays, and limestones were accumulated at the same period, the fossils varying to a greater or less extent, according to depth of water, character of sea-bottom, and other conditions. These facts were afterwards recognised.

Smith, however, noted the local absence of certain divisions "from the *unconformableness* of some of the other Strata."¹ He further recognised the distinction between the fossils of the regularly disposed formations and those of the gravels, the former being well preserved, and the latter greatly rounded by attrition. The organic remains of the gravels, called "alluvial fossils," were noted to be "as various as the strata from whence they have been dislodged," and "the most indubitable effects of a great body of water passing over the surface of the earth, with violence sufficient to tear up fragments of the strata."

The works on fossils to which Smith had access, probably through his friends Richardson and Townsend, were those of Plot and Lhwyd, Morton on Northamptonshire, and the local

¹ *Stratigraphical System of Organised Fossils*, 1817.

work by John Walcott, entitled *Descriptions and Figures of Petrifactions, Found in the Quarries, Gravel-Pits, etc., near Bath, 1779*. This little volume contained good figures of many fossils such as the Pear-encrinite of Bradford, and the species afterwards known as *Terebratula coarctata*, *Spirifera Walcottii*, *Lima gigantea*, etc. Smith's knowledge, however, was essentially local; and, as remarked by his nephew, John Phillips, he never quitted for a day the island on which his researches had been concentrated.

That Smith, at that early date, had not succeeded in correlating all the main divisions of the British strata is natural; but, as Sedgwick remarked in 1831, his "arbitrary and somewhat uncouth terms . . . have long become engrafted into the conventional language of English geologists, and, through their influence, have been, in part, also adopted by the naturalists of the Continent."

Of the names introduced by Smith, those of Red Marl, Lias, Forest Marble, Cornbrash, and Crag (provincial English terms), and those of Kelloways or Kellaways, Portland and Purbeck Beds, and London Clay (geographical names), have been maintained as distinctive terms for British geological formations. Others, modified as Liasian, Callovian (from Kellaways), Portlandian, and Purbeckian, are used abroad

to mark epochs of geological time, irrespective of the stratigraphical characters which they possess at the typical localities.

The scientific study of fossil organic remains received a great impetus in France at the close of the eighteenth century, and in the early part of the nineteenth century, from the researches of Lamarck and Cuvier.

LAMARCK (1744-1829), who had devoted attention in early years to botany, and afterwards to zoölogy, became especially distinguished by his great work on *Animaux sans Vertèbres*, which was published in 1801, and considerably amplified during the years 1815-22. He appears for the first time to have restricted the term fossil to organic remains; and, what is of signal importance, he connected "his investigation of living forms with an examination of the extinct types preserved in the various formations of the earth's crust"; so that, as remarked by Sir Archibald Geikie,¹ he became entitled to the name of "Founder of Invertebrate Palæontology." He recognised the vast antiquity of the globe, and perceived that, while the majority of fossil shells belonged to marine forms, they represented different depths of sea-bottom, and were accumulated more or less tranquilly with the sediments in which they were buried.

¹ Article on "Lamarck and Playfair," *Geol. Mag.* (1906), pp. 145, etc.

Further, Lamarck was "the most philosophical zoölogist of his time, and the pioneer of the modern doctrine of biological evolution."

He saw the difficulty of fixing the limits of genera and species, as some naturalists were led to regard as varieties what others described as species; and he observed that the forms varied according to changes in natural conditions. He described the Tertiary mollusca of the Paris Basin in a work published 1802-06. As remarked by Sir A. Geikie (1905): "During the last ten years of his long life he suffered from total blindness, and had to rely on the affectionate devotion of his eldest daughter for the completion of such works as he had in progress before his eyesight failed."

CUVIER (1769-1832), universally regarded as the "Founder of Vertebrate Palæontology," commenced his researches in 1796, the year after he was appointed Professor of Anatomy at the Museum of Natural History at Paris. His chief work, *Recherches sur les Ossements Fossiles de Quadrupèdes*, in four volumes, was published in 1812. Among the more noteworthy animals which he described were the mammals from the Lower Tertiary (Eocene and Oligocene) strata of France, mostly obtained from the gypsum quarries of Montmartre, in the neighbourhood of Paris. At the time these were the earliest fossil mammals that had been discovered.

The *Anoplotherium* and *Palæotherium* were first described in 1804, and these tapir-like animals were afterwards found in the Oligocene beds of the Isle of Wight. Another animal, the *Lophiodon*, more closely allied to the tapir, was described in 1822, and it has been obtained in the Eocene beds of Bracklesham. Owen remarked^{*} that the researches of Cuvier "which resulted in the restoration of the *Palæotherium* and *Anoplotherium* are the most instructive which the palæontologist can study."

The gigantic sloth of South America, the *Megatherium*, about eighteen feet in length, was first obtained from Pleistocene deposits in Buenos Aires, in 1789; and its affinities were determined and the genus was named by Cuvier. Among reptiles he described the *Pterodactylus*, in 1809.

Cuvier was also author of an essay on the Theory of the Earth, which, as we learn from Sir A. Geikie, was prefixed to his work on *Ossements Fossiles*, and afterwards published separately under the title *Discours sur les Révolutions de la Surface du Globe*. Both the essay and the discourse were translated into English, and published under their separate titles.

In an obituary notice, Murchison remarked of Cuvier: "He it was who, removing from

^{*} *Palæontology*, ed. 2, 1861, p. 368.

geology the incumbrance of errors and conceits heaped on it by cosmogonists, contributed more than any individual of this [nineteenth] century to raise it to the place which it is assuming among the exacter sciences."

While the main divisions in the Secondary strata were determined by William Smith, the divisions in the older Tertiary strata were first clearly worked out by Cuvier and ALEXANDRE BRONGNIART (1770-1847), in an essay communicated to the *Journal des Mines* in 1808, but amplified and issued separately in 1811.

They recognised the occurrence of marine and freshwater deposits, and noticed the fossils peculiar to certain strata, including some of the remarkable vertebrate remains before mentioned.

The title of their volume was *Essai sur la Géographie Minéralogique des Environs de Paris*, and it proved to be of the highest importance in teaching the true method of working out the life-history of the geological series, on the combined evidence of mineral characters and stratigraphical sequence, together with that of the successive groups of fossils.

CHAPTER III

GEOLOGY IN THE EARLY PART OF THE NINETEENTH CENTURY

MINERALOGY had been studied with ardour during the eighteenth century, and questions of classification by chemical composition, by crystalline form, and other eternal characters were duly debated.

Romé de l'Isle (1736-1790) in 1772 and 1783 advocated the importance of the geometrical form in the classification of minerals; but, according to Whewell, the founder of the science of crystallography was the Abbé Haüy (1742-1822), whose principal works date in publication from 1801 to 1822.¹

Many individuals formed collections of minerals, some for purposes of study, others as "curios."

Addison, in *The Spectator* (Letter 94, of June 18, 1711), had remarked: "I remember Mr. Boyle, speaking of a certain mineral, tells us

¹ See *Report on the Structure of Crystals*, Brit. Assoc., 1901.

that a man may consume his whole life in the study of it without arriving at the knowledge of all its qualities"; and it is noteworthy that nearly a century later Count de Bournon published, in 1808, three quarto volumes on Calc-spar; but, judging from the title, *Traité Complet de la Chaux Carbonatée et de l'Arragonite*, the author must have believed that there was little or nothing more to be said on the subject.

At the beginning of the nineteenth century there appears to have been very little definite teaching of geology in Britain. In London the best collection of fossils and minerals was to be found at the Royal Institution, under the charge of Humphry Davy.

With regard to fossils, one of the earliest systematic works published in England was that issued by JAMES PARKINSON, a medical man resident at Hoxton, under the title *Organic Remains of a Former World: An Examination of the Mineralised Remains of the Vegetables and Animals of the Antediluvian World; generally called Extraneous Fossils*, 3 vols., 1804-1811.

The Foundation of the Geological Society of London

Chemists and mineralogists were, however, becoming interested in the new science of geology, and in the course of the year 1807 several

distinguished representatives in the respective sciences united with others interested in natural philosophy and geology to form the Geological Society of London.¹

The actual founders of the Society numbered thirteen, and their object in the beginning was to constitute "a little talking geological dinner club." The first meeting was held at the Freemasons' Tavern, Great Queen Street, on November 13, 1807, and then formal regulations were drawn up. The thirteen members comprised:

Arthur Aikin, chemist and mineralogist; William Allen, analytical chemist (founder of the firm of Allen and Hanbury); William Babington, M.D., a famous physician, and author of works on mineralogy; Count de Bournon, F.R.S., mineralogist; Humphry Davy, F.R.S., professor of chemistry at the Royal Institution; James Franck, M.D.; George Bellas Greenough (1778-1855), M.P., F.R.S., a man of independent means, a pupil of Werner, and an enthusiastic geologist; Richard Knight; James Laird, M.D., mineralogist; James Parkinson, F.R.C.S. (died 1824); William Hasledine Pepys, chemist and natural philosopher; Richard Phillips, chemist; William Phillips (1773-1828), printer and bookseller, a distinguished mineralogist and geologist: his earliest geological work was a detailed study of the chalk in the south-east of England.

¹ See H. B. Woodward (1907).

Early Part of Nineteenth Century 59

Among these members Parkinson was the representative of palæontology, William Phillips of stratigraphical geology, and Greenough, who for many years was the main supporter of the Society, was the representative of general geology.

In 1807 the Geological Society was strengthened by the election as honorary members of the Rev. J. J. Conybeare, of Oxford; R. Jameson, Professor of Natural History at Edinburgh; Dr. John Kidd, Professor of Chemistry at Oxford; John Playfair, Professor of Natural Philosophy at Edinburgh; the Rev. Joseph Townsend, Rector of Pewsey, and others.

The Society, as stated in January, 1808, "was instituted for the purpose of making geologists acquainted with each other, of stimulating their zeal, of inducing them to adopt one nomenclature, of facilitating the communication of new facts, and of contributing to the advancement of Geological Science, more particularly as connected with the mineral history of the British Isles." It is noteworthy that at their meetings the members did not enter into the Wernerian and Huttonian controversies.

In the earlier volumes of the Society's published *Transactions* most of the papers dealt with mineralogical and petrological subjects; but Parkinson, in an account of the strata in the neighbourhood of London and their fossil

remains, called special attention to the observations and conclusions of William Smith.

JOHN MACCULLOCH, M.D. (1773-1835), joined the Society in 1808, and to him the members were at first largely indebted for important papers on the mineralogy of the islands of Guernsey, Jersey, etc.; and, later on, for others on the rocks of various parts of Scotland.

In the year 1808 Leonard Horner, James Sowerby, and Dr. J. F. Berger became members of the Society; in 1809 Thomas Webster; in 1811 the Rev. W. D. Conybeare; in 1812 W. H. Wollaston; in 1813 William Buckland; in 1816 W. H. Fitton; in 1817 Henry T. De la Beche; in 1818 Daubeny, Mantell, and Sedgwick; in 1819 Lyell and Henslow; in 1820 Thomas Weaver; in 1823 J. J. Bigsby; and in 1824 G. Poulett Scrope and Murchison. These records of the dates when some of the great masters of geology in Britain joined the Geological Society are of considerable historic interest.

Geology at the Universities.

The lectures of JOHN KIDD, M.D. (1775-1851), who was Professor of Chemistry at Oxford during the years 1805-10, for the first time introduced into the university the subject of geology, in which he took keen interest. He was author of two volumes on mineralogy

(1809), and of *A Geological Essay* (1815). In Oxford the Ashmolean Museum fulfilled the part taken by the Woodwardian Museum at Cambridge in supplying the necessary illustrative specimens. Moreover, in the dark chambers under the Museum, as we are told by John Phillips, "nearly all the scientific teaching at Oxford had been accomplished since the days of Robert Plot,"¹ until about the middle of the nineteenth century. In Dr. Kidd's "subterranean class-room" Buckland, J. J., and W. D. Conybeare, Daubeny (who succeeded Kidd as Aldrichian Professor of Chemistry), W. J. Broderip, and others, received some of their earliest geological lessons.

The association of geology with chemistry and other sciences in those days is interesting, for Daubeny, in many respects a geologist as well as a chemist, became, in 1834, Professor of Botany at Oxford; and Henslow, who succeeded E. D. Clarke as Professor of Mineralogy at Cambridge, afterwards became Professor of Botany, holding the two professorships for about two years, until 1828, when Whewell (a master of all sciences) was appointed to the chair of mineralogy.

Dr. Kidd resigned the Readership of Mineralogy at Oxford in 1813, and was succeeded by

¹ *Obit. of C. G. B. Daubeny*, Ashmolean Soc., 1868.

WILLIAM BUCKLAND (1784-1856), who taught mineralogy and geology. His lectures and his speeches were characterised by the "union of the most playful fancy with the most profound reflections"; and there is no doubt that his happy manner of imparting information, his great knowledge of palæontology in general and of osteology in particular, and his researches in field geology, enabled him to exercise a potent influence on the progress of geology. "His courses attracted in a high degree the attention and admiration of the university, and very largely contributed to the public recognition of geology as a science by the endowment, in 1819, of a Professorship."¹

ADAM SEDGWICK (1785-1873), who had been a mathematical tutor, was appointed Woodwardian Professor at Cambridge in 1818. Almost fresh to the study, he took it up with great enthusiasm, and his field-work was pursued in most difficult districts with a vigour unsurpassed by any of his contemporaries. Like Buckland, he excelled in eloquence, and he roused the interest and zeal of many who, in after years, became distinguished geologists.

Meanwhile, in Edinburgh, Robert Jameson was continuing his work as Professor of Natural

¹ *Life of Buckland*, by Mrs. Gordon (1894). See also Portlock, *Obit. Notice* in address to Geol. Soc., 1857, and Sollas (1905), p. 219.



WILLIAM BUCKLAND.
From a painting by T. C. Thomson.

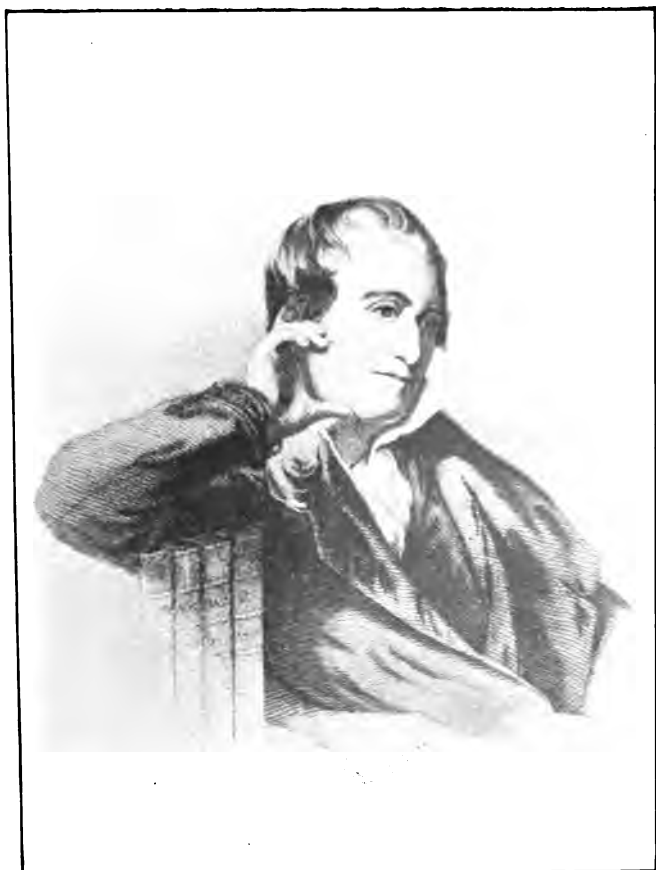
History, teaching geology among other subjects. He was author of the *Mineralogy of the Scottish Isles* (1800), and of a *System of Mineralogy*, in three volumes (1804-1808). The third volume of the last-mentioned work was a "Treatise on Geognosy," and as such it was among the earliest British text-books on the subject.

Another book of note was *An Introduction to Geology*, by Robert Bakewell, of which the first edition was published in 1813 and the fifth in 1838. Lyell's interest in geology was awakened by a perusal of this work, a copy of which he found in his father's library.¹

Abroad, Werner continued his lectures on geology and mining until his death, in 1817, when he was succeeded in the chair at Freiburg by his pupil, Friedrich Mohs (1772-1839), the distinguished mineralogist.

In France, Alexandre Brongniart, who was distinguished for his knowledge of chemistry, mineralogy, stratigraphy, and zoölogy, succeeded Haüy, in 1822, as Professor of Mineralogy in the Muscum of Natural History at Paris. In that country the *Traité de Géognosie*, by d'Aubuisson, issued in 1819, was one of the earlier text-books, and in it the work of William Smith was duly acknowledged. In Italy an *Introduzione alla Geologia*, by S. Breislak, was published in 1811.

¹ See Bonney (1901), p. 19.



WILLIAM MACLURE.
From an engraving by D. C. Hinman.

Early Geological Maps

It is a remarkable fact that a geological map of what was then included in the United States, the region east of the Mississippi, was published as early as 1809 by the American Philosophical Society. It was the work of WILLIAM MACLURE (1763-1840), who, born at Ayr in Scotland, settled in Virginia in 1796. In 1807, as Buckland remarked, he had commenced "single-handed the Herculean task of exploring the geology of the United States." After two years he had completed the first map and memoir of the country; and eight years later he published a second paper, which was reprinted at Philadelphia in 1817, and issued under the title of *Observations on the Geology of the United States of America*. In the course of his geological survey, "he went forth, with his hammer in hand and his wallet on his shoulder, pursuing his researches in every direction, often amid pathless tracts and dreary solitudes, until he had crossed and recrossed the Allegheny Mountains no less than fifty times"; and his observations were made in almost every State and Territory in the Union, from the River St. Lawrence to the Gulf of Mexico.

On Maclure's first map it was natural that only the broadest outlines of the main features

¹ See Merrill (1906), pp. 217, etc.

in the geology were indicated. They were coloured, under the headings of Primitive, Transition, Secondary, and Alluvial rocks, with a separate tablet for rock salt, from observations made on salt licks and salt springs.

The Alluvial rocks included strata now grouped as Tertiary and Quaternary; but the general outlines of these and other formations show remarkable knowledge, when we compare the map with that of Mr. Bailey Willis, dated 1903.¹

That Maclure should be known as the "Father of American Geology" is fully justified by the work he accomplished as a pioneer; and it is interesting to learn that in speculations regarding the globe he recommended attention to "the probable effects resulting from the regular operations of the great laws of nature," and that he pointed out the advantages to be derived from a study of the strata and their soils.

In Ireland the first geological map was constructed by RICHARD J. GRIFFITH (1784-1878), whose name is so often quoted at the present day as "Griffith's valuation" in connection with local and public assessments.

The earliest of Griffith's maps, based mostly on personal research, was issued in 1815; but his "first complete geological map of Ireland"

¹ Issued in *Geology*, by Chamberlin and Salisbury, vol. ii., 1906, p. 218.

was published in 1838. At a subsequent date he prepared a larger and more important map of the country, on the scale of an inch to four miles, the latest revision of which was published in 1855.¹

Works on Fossils

The famous work on *The Mineral Conchology of Great Britain*, commenced by JAMES SOWERBY (1757-1822) and continued by his son, JAMES DE CARLE SOWERBY (1787-1871), dates from 1812 to 1845. The authors were systematic naturalists and expert draughtsmen, and their illustrations, like those in William Smith's *Strata Identified by Organised Fossils*, were coloured to represent the actual appearance of the specimens, often with portions of the matrix in which the fossil was embedded. The geologist and the collector, therefore, could readily identify his fossils in those happy days when genera and species were treated on broad lines.

Information was not always given with regard to the precise horizon or geological formation from which the fossils were gathered; and, indeed, some were obtained from the Stony Drift (subsequently known as boulder clay), as well as from various Drift gravels. Nevertheless,

¹ See Judd, *Geol. Mag.*, 1898, p. 148.

Early Part of Nineteenth Century 69

the work was a most important aid to the progress of geological research and a stimulus to



JAMES DE CARLE SOWERBY.
From a Photograph.

collectors, and, although superseded in great measure by the publications of the Palæonto-

graphical Society, it will ever remain a work of reference cherished for its original descriptions and excellent figures.

In Germany, BARON VON SCHLOTHEIM (1764–1832), who had been a pupil of Werner, studied the relations of fossils to the strata in which they were embedded, and published a work on fossil plants in 1804. He issued a more important general work, *Die Petrefactenkunde*, in 1820, with the addition of a folio atlas in 1822, and described the fossils according to the binomial system.

GOLDFUSS (1782–1848) issued during the years 1826–1844 his *Petrefacta Germaniæ*, a standard work of reference, though incomplete. In this he was assisted by COUNT MÜNSTER (1776–1844), who had made a particular study of the fossils from the lithographic stone of Solenhofen, in Bavaria.

BROCCHI (1772–1826), one of the most distinguished of Italian geologists, who had been a pupil of Werner, published descriptions and figures of the fossil mollusca of the Subapennine (Miocene and Pliocene) strata of Italy in 1814 under the title *Conchiologia Fossile Subapennina*.

Practical Geology

The progress of knowledge, as of old, was due largely to the development of economic pro-

ducts, and to the information thereby acquired. Records of strata passed through in mine-shafts and well-sinkings were from time to time published: important information on soils, strata, and minerals being gathered by writers who contributed reports to the old Board of Agriculture. Among the authors was JOHN FAREY (1766-1826), who acknowledged that William Smith was his "master and instructor in mineral surveying."

To him we owe the *General View of the Agriculture and Minerals of Derbyshire*, published in two volumes, 1811 and 1813. In the first volume Farey gave a brief account of the upper part of the British series of strata, from the "*Sand* which occupies *Bagshot Heath*" to the red-ground above the Coal-measures, and observed that there a natural division of the British strata was marked out. He likewise published an instructive series of coloured diagrams to explain the nature of faults or dislocations, and tilts of the strata, also of the subsequent denudation—diagrams which may be regarded as the precursors of the famous models afterwards constructed by Sopwith. Farey's descriptions of the Derbyshire strata, of the Coal-measures and underlying Carboniferous grits, limestone-shale, limestone, and bands of toadstone; of the lead-mines, the caverns and swallow-holes, render his work of per-

manent value, and one of the classics of English geology.

Progress in British Geology

The volume published by the Rev. JOSEPH TOWNSEND in 1813, entitled *The Character of Moses Established for Veracity as an Historian: Recording Events from the Creation to the Deluge*, was another work of considerable importance, although, unfortunately, its merits were obscured by its title. It embodied the results of investigations extending over more than fifty years on mineralogy and on the strata and fossils in the British Isles and in various parts of Europe. While acknowledging his indebtedness to distinguished mineralogists abroad, the author observed that "the person by whom he was first led to trace and clearly to ascertain the succession of strata in our Island, is William Smith." Although the work includes much that is in harmony with its title, it contains interesting local accounts of the strata, fossils, economic products, springs, etc., in various parts of Britain, as well as abroad, and twenty-one plates of fossils. The results of much of William Smith's work were here for the first time published, with a good deal of additional information based on the author's own researches. At the time of publication it was

the best English work on stratigraphical and topographical geology.

In 1818 WILLIAM PHILLIPS published *A Selection of Facts from the Best Authorities, arranged so as to form an outline of the Geology of England and Wales*. Therein a clear account was given of the succession of formations down to the Old Red Sandstone, the older rocks being grouped under the terms greywacke, clayslate, etc. Different ages of granite were admitted; and an excellent table of the "Order of Superposition of Strata in the British Islands" was contributed by Buckland.

AMI BOUÉ (1794-1881), who had been a pupil of Jameson, was author of the earliest general account of Scotland, the *Essai Géologique sur l'Écosse*, published in 1820. This work, which contained much original information, summarised the knowledge on the various rock-formations, the granites, gneiss and schists, grauwacke, Old Red Sandstone, and coal-bearing strata, the Lias, and volcanic rocks.

GREENOUGH, who had published in 1819 *A Critical Examination of the First Principles of Geology*, the chief merit of which appears to have lain in the disproof of "many of the crude notions of former days," had devoted many years of labour and personal observation to the preparation of a geological map of England and Wales, which was issued by the Geological

Society of London in 1820, though dated 1819. He had been assisted by Buckland, Conybeare, De la Beche, and others, and he naturally benefited in the end by the original map of William Smith.

The publication of Greenough's map to a certain extent superseded that earlier work, and a somewhat tardy acknowledgment of the advantage derived from it was made when the Society issued the third edition in 1865, and inserted in the title that it was "on the basis of the original Map of William Smith, 1815."

The progress of geology at this period (as at many subsequent intervals) was not uninterrupted by the publication of views of a retrograde nature. Greenough, in his above-noted volume, expressed opposition to the Huttonian doctrines; and MacCulloch appears to have been so absorbed in rocks, from a mineralogical point of view, as to have acquired little knowledge of their stratigraphical succession and of the chronological value of fossils.

MacCulloch, who may be regarded as a pioneer in petrology, published in 1821 *A Geological Classification of Rocks, with descriptive synopses of the species and varieties, comprising the Elements of Practical Geology*. He then remarked: "With respect to the order of succession in the primary class, the claim of granite to the first or lowest place is unques-

tioned"; and after it "no further certainty can be obtained as to the next rock, or the first of the strata; since they are all occasionally found in contact with it." He admitted that "one rock may, in some places, follow another in immediate succession, when in others the two are separated by different intervening strata"; but his knowledge of British formations was limited, he appears to have paid little attention to the observations of others, and his descriptions are essentially mineralogical. With regard to the organic species, he considered that "scarcely any admit of being certainly referred to a constant order of geological position, or can be traced exclusively to particular strata."

The Great Masters of Geology

Despite the publication by a few of the leading geologists of views that are to be regarded as heterodox, the period extending from about 1820 to 1840 may be said to be that of the Great Masters of Geology: a period characterised by strenuous field-work and by many grand discoveries in various parts of Europe and America. Progress, in fact, was ensured by the application of the sound principles gathered from the teachings of Hutton, William Smith, Cuvier, and others. The period during which Buckland was in his prime, when Sedgwick, Murchison,

Lyell, De la Beche, Von Buch, Boué, Elie de Beaumont, Omalius d'Halloy, and others, were doing brilliant work, has been also described as the "Golden Age of Geology."¹

Mineralogy appears to have been studied by fewer zealous workers than before; but the Geological Society of London had one of the ablest representatives in W. H. WOLLASTON (1766-1828), who took particular interest in their labours. Born at East Dereham, in Norfolk, he took the degree of M.D., practised for a short time as a medical man, and then devoted himself to scientific research. Distinguished on many subjects, and regarded as "a mineralogist of the first order," his advice was constantly sought. To geologists he is best known as the inventor of the reflecting goniometer for measuring the angles of crystals, and as the founder of the Wollaston Medal, the highest award of merit given by the Council of the Geological Society.

LEOPOLD VON BUCH (1774-1853), referred to by Humboldt as the greatest geologist of his time, and by Sir Archibald Geikie as "the most illustrious geologist that Germany has produced," was a pupil of Werner, a man of independent means, and a bachelor. Explorations in Auvergne in 1802 convinced him that basalt,

¹ See Sollas (1907).

surface were somewhat fully treated. The author has been described as an original thinker of great merit, but his views were derived from an exhaustive study of the literature; and it was as a philosophical historian rather than as a geologist that he influenced the progress of the science.¹

CHARLES LYELL (1797-1875), who was born at Kinnordy, in Forfarshire, was educated at Oxford, and thither he went with some interest in geology, which was developed by the fascinating lectures of Buckland. Intending at one period to adopt the Law as a profession, he studied the subject, and was called to the Bar in 1825. The training, no doubt, was of essential importance to him; but his interests were gradually concentrated on geology, and although he accepted in 1831 the chair of geology at King's College, London, he had sufficient means to be independent, and soon abandoned professorial work. In 1825 he commenced to contribute papers on geology, and in the following year made important additions to the knowledge of the Tertiary strata of Hampshire and Dorset. By extended travel and personal observation, and by a study of the publications on the subject, he qualified himself for the great task which may

¹ See review of *Karl Ernst Adolf von Hoff, der Bahnbrecher moderner Geologie*, by Dr. Otto Reich, in *Nature*, June 8, 1905.

regarded as of aqueous origin by his teacher, was in reality an eruptive rock; and journeys in Scandinavia led him to maintain that portions of Sweden were undergoing slow elevation. He made investigations in Switzerland and Italy, and recognised also that mountains were due to the effects of disturbance and upheaval, and in many instances had a granitic axis. After great labour he produced the first general geological map of Germany, which was published in 1824. He enlarged our knowledge of other regions with reference to volcanic phenomena at different periods, and especially by his great work on the Canary Island. Moreover, turning his attention to palæontology, he described sundry Ammonites, Brachiopods, and Cystideans in memoirs, which, as Edward Forbes remarked, are valuable "both as descriptive and as philosophic essays." Indeed, his palæontological teachings with regard to the stratigraphical and chronological importance of fossils exercised great influence on the progress of comparative geology.

In views concerning basalt Von Buch was closely followed by another pupil of Werner, d'Aubuisson de Voisins, who supported his teacher in 1803, and recanted in the following year.

Among travellers, ALEXANDER VON HUMBOLDT (1769-1859), born at Berlin, and de-



LEOPOLD VON BUCH.
From a lithographic portrait.

scribed by John Phillips as "universal in genius and cosmopolitan in feeling," though not specially a geologist, made observations in various parts of the world on mineralogy, volcanoes, mountain-chains, and metamorphism, as well as on natural history.

He published, in 1823, *Essai Géognostique sur le Gisement des Roches dans les Deux Hémisphères*, a work dealing with the superposition of rocks; and in this he introduced the names *Jurassique* and *Jura formation*.

His great work, summarising his observations and views on the physical phenomena of the universe, was the *Kosmos*, which was translated into English and issued in several editions.

Fitton, in his address to the Geological Society in 1828, referred to the evidence of the activity of volcanic agents during all the periods of geological time, and to the fact that the Huttonian Theory had been confirmed in many of its leading propositions. He observed that, while the asperity of the controversy had been to a great extent assuaged by the eloquent and dignified expositions of Playfair, nevertheless the more correct views on the subject of volcanic action, and the practical extinction of the controversy between the Wernerians and Huttonians, were due to the observations of Von Buch and Von Humboldt.

DAUBENY (1795-1867), in 1819 and subse-

Early Part of Nineteenth Century 81

quent years, studied the volcanic phenomena of Auvergne and other regions, and published in 1826 *A Description of Active and Extinct Volcanoes*. He gave support to the views of Gay-Lussac and Davy that water coming in contact with uncombined bases, such as potassium, etc., beneath the oxydised crust was an efficient cause of the high temperature which led to earthquake movements and volcanic eruptions.

Meanwhile, G. POULETT SCROPE (1797-1876), by his studies of the volcanic regions of Central France and elsewhere, did much to further the views of Hutton and Playfair; and by his observations on the fluviatile erosion of the valleys he confirmed and amplified those of Desmarests. His *Considerations on Volcanoes* was published in 1825, and his *Memoir on the Geology of Central France* in 1827; later editions of both works, under somewhat modified titles, were published.

Progress in British Geology

Although the occurrence of fossil bones of large dimensions had been known to occur in the cliffs of Dorset, as well as in other parts of England, it was not until 1811 that the first great Saurian from Lyme Regis was brought into scientific notice. Some account of the remains was published in 1814 by Sir Everard

Home, and five years later he gave the name *Proteosaurus*; but it was afterwards ascertained that Koenig had, in 1818, described the same genus under the name *Ichthyosaurus*, and consequently that name was adopted. The Dorset specimen was obtained by Mary Anning, of Lyme Regis, daughter of a cabinet-maker, who had been accustomed to add to his earnings by the sale of fossils, which were displayed on a table in front of his shop.

Mary Anning (1799–1847) was but a child when her first great fossil treasure was obtained. Her father had died in 1810; and the support of the family depended on the sale of fossils, which were purchased by visitors and by passengers who passed through the town on coaches. Although in no sense a scientific worker, she did much to advance knowledge by her diligence and aptitude in collecting specimens. In 1821 she obtained remains of another reptile, described by Conybeare under the name *Plesiosaurus*; and in 1828 she obtained, for the first time in England, the Pterodactyl, of which the species described by Buckland is now known as *Dimorphodon macronyx*.


The little work by William Phillips, to which reference has been made, was reconstructed and greatly amplified in 1822, when it was issued under the title of *Outlines of the Geology of England and Wales, with an Introductory Com-*

pendium of the General Principles of that Science, and Comparative Views of the Structure of Foreign Countries, Part I., by the Rev. W. D. CONYBEARE (1787-1857) and William Phillips. In this work only the strata down to the Old Red Sandstone were dealt with. It was intended to issue the second part on the older formations; but William Phillips died in 1828, and, although a plan was made for a joint volume by Conybeare and Sedgwick, it was never carried out. Conybeare became Dean of Llandaff, and Sedgwick was fully occupied with various duties at Cambridge and Norwich. Whewell described the work of Conybeare and Phillips as "a profound and instructive treatise," and it unquestionably gave a great impulse to the study of descriptive and topographic geology.

From the Introduction we learn of the orderly superposition of the main formations, and the distribution in them of organic remains in groups more and more distinct from the living forms, according to age—the shells in strata above the Chalk being well preserved, and some retaining their original colour. The Crag was recognised as the newest of the regular strata. We further learn that rocks of approximately similar character occur throughout the geological series, differing in texture and other characters mainly by the changes wrought by time.

Vertical and overfolded strata were noted, and changes in the relative level of land and sea were referred to decrease in the amount of water, and to upheaval and depression. Moreover, the raising of the sea-bed by deposition of sediment was suggested as one cause of change in the level of the water. Remarks were also made on the apparent identity of fossils in distant countries, whereas recent species differ so much in widely separated areas.

With regard to the excavation of valleys it was pointed out that some in the Weald and others near Bristol had been excavated through crests of hills, to the level of which the streams, as they now exist, could not rise; and it was suggested that the channels must have been eroded by large sheets of water sweeping over extensive tracts, and due either to diluvial agency or to the draining off of the sea from uplifted land. Attention was drawn to the small amount of denudation now going on, as evidenced by the preservation of various ancient earthworks; and it was remarked that the defect in certain theories of the aqueous erosion of valleys was that "they look to no other supply of that agency than the streams (often inconsiderable rills) which now flow through them, borrowing liberally from time what they confessedly want in force." Conybeare enlarged upon this subject in a paper on the valley of the



Thames; but he was not right when he maintained that the waters in the valley could never have been adequate to transport the coarser materials.

He dissented from the view that the causes now in action, and those alone, have produced the changes in the face of nature. Volcanic agency was held to have been greater during the earlier periods of geological history. Nevertheless, while noting the elevation of Oolitic strata in Alpine regions, he was compelled to allow that comparatively recent strata exhibit, as in the Isle of Wight, great derangements; and that we "must be prepared to admit, without being startled, causes of a force and energy greatly exceeding those with which we are acquainted from actual observation."

Geology and the Deluge

In his *Reliquiæ Diluvianæ*, published in 1823, Buckland recorded "Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on other Geological Phenomena, attesting the action of an Universal Deluge." It is a valuable work at the present day, so far as concerns the record of facts.

Buckland's views respecting the deluge were, however, criticised, with good judgment, by his former teacher, John Kidd. He remarked:

Time was also, and indeed within the last century, when the shells and other organic remains, which are imbedded in the chalk and other solid strata, were considered to be the remains and proofs of the Mosaic deluge; and yet at the present day, without any fear of injuring the credibility of the Scriptures, they are admitted very generally to have been deposited anteriorly to the Mosaic deluge. And who will venture to say, in the infancy of a science like geology, that the same change of opinion may not happen with respect to the organic remains of the gravel beds and caverns . . . by far the greater number of the organic remains of the gravel, as of the caverns, belong to species not known now to exist.¹

Eventually Buckland and Sedgwick abandoned the view that geological proofs of the Mosaic deluge were to be found in the great accumulations of diluvial gravel and other superficial deposits; and, although they did not deny the reality of an historic deluge, they perceived that geology furnished no evidence of such a universal flood as that depicted in the Mosaic record.

It is not, however, surprising that the Superficial or Drift deposits were taken as evidence of the Noachian deluge. Such widespread deposits, made up of more or less rolled frag-

¹ Bridgewater Treatise, *On the Adaptation of External Nature to the Physical Condition of Man*, 1833, pp. 182, etc.

ments of the regularly stratified formations, with derivative or *remanié* fossils of various kinds and ages, intermingled with remains of the larger and comparatively recent mammalia, were suggestive of torrential action. Indeed, it is now generally admitted that the melting of the ice, which extended over large areas during the Pleistocene period, gave rise to extensive floods and tumultuous or diluvial deposits; and suggestions have been made that this Glacial or catastrophic period might have originated the traditions of a universal flood, as there is reason to believe that man existed during, if not before, the Great Ice Age.¹

Suess has given an elaborate account of the records and traditions relating to the Noachian deluge—"The most stupendous natural event for which we have human testimony"—and has summed up his results as follows:

The event known as the *Deluge* took place in the region of the Lower Euphrates, and was connected with an extensive and devastating inundation of the Mesopotamian plain.

The chief cause was an earthquake of considerable violence in the region of the Persian Gulf, or to the south of it, which was preceded by several smaller concussions.

¹ See R. H. Tiddeman, *Work and Problems of the Victoria Cave Exploration*, 1875.

It is most probable that during the period of the most violent shocks a cyclone came from the south out of the Persian Gulf.

The traditions of other races do not justify us in asserting that the flood extended over the whole earth, or, indeed, beyond the lower course of the Euphrates and Tigris.


The "rising of great quantities of water from the deep" is stated by Suess to be a characteristic accompaniment of earthquakes in the alluvial districts of great rivers; but rain and subterranean water were merely accessory elements. The deluge as a whole came from the water of the Persian Gulf, driven by earthquake-shocks over the plain at the mouths of the Euphrates, and accompanied by cyclonic rain-storms.¹

Local Researches on Fossils and Stratigraphical Geology

Parkinson issued, in 1822, a small work, *Outlines of Oryctology: An Introduction to the Study of Fossil Organic Remains, especially of those found in the British Strata*—a work intended "as a humble subsidiary" to the geology by Conybeare and Phillips.

The term "Oryctology" was in use in the middle of the eighteenth century for the study of fossils, which then included almost every sub-

¹ *The Face of the Earth* (English translation), vol. i., 1904, pp. 18, 31, 57, 71, 72.



stance dug out of the earth. The name was restricted by Parkinson to organic remains, including the casts or moulds of various fossil animals or plants.

It is interesting to note that a special work dealing with one group of animals, *A Natural History of the Crinoidea*, was issued in 1821 by J. S. Miller, of Bristol, a native of Dantzic, whose original name was Müller.

Researches were now carried on in various countries, where a careful study of the strata and their organic remains yielded almost everywhere a rich harvest of new and interesting information.

THOMAS WEBSTER (1773-1844) was the first to apply the work of Cuvier and Brongniart on the Paris Basin to the elucidation of the earlier Tertiary strata in England; and as early as 1814 he had described the Freshwater Formations in the Isle of Wight, while two years later he contributed much geological information on the Chalk and Tertiary strata to Sir Henry Englefield's folio work on the Isle of Wight and adjacent parts of Dorset. Especially interesting and important were the illustrative geological sections of the disturbed strata drawn by Webster for that volume.

H. T. DE LA BECHE (1796-1855)—“the last male representative of a family of Norman barons who came to England with the Conqueror”—

was educated at the Military College of Great Marlow,¹ and became one of the most accomplished of geologists. During the years 1822 to 1826 he described in detail the secondary strata in the neighbourhood of Lyme Regis, publishing excellent accounts of the Lias and Cretaceous rocks, accompanied by pictorial coloured sections of the cliffs, drawn with exceptional skill. With Conybeare, he prepared a geological map of the country around Bath (on the scale of one inch to two miles), which was published in 1823; and with Buckland he later on gave a clear and admirable account of the geology of Weymouth. Possessed of independent means, he was enabled to give his whole time to geological research.

Another geologist who rendered distinguished service, WILLIAM LONSDALE (1794-1871), was born in Bath, became an ensign in the King's Own Regiment in 1810, served in the Peninsular War, and was present at the battle of Waterloo. He retired as Lieutenant, and, according to his own statement, he became a geologist through hearing the conversation of two ladies about a fossil in the library at the Literary Institution at Bath. He determined to investigate the neighbourhood; and it is recorded by Sir A. Geikie that in 1825 Murchison accidentally met him

¹ See Geikie, *Memoir of Sir A. C. Ramsay*, 1895, p. 34.

in a quarry, "a tall, grave man, with a huge hammer on his shoulder," who proved to be so full of information that Murchison spent some days at Bath under his guidance. This introduction, no doubt, led to the appointment, in 1829, of Lonsdale as Curator and Librarian of the Geological Society of London at Somerset House, where he remained until 1842. In 1829 he read before the Society a paper on the Oolitic district near Bath, illustrated by sheets of the Ordnance one-inch map, which had been previously exhibited at the anniversary meeting in 1828. Then Fitton had remarked that "the maps thus coloured are probably as complete specimens of geological illustration as ever have been produced." The paper itself was a model of careful and accurate observation. Lonsdale subsequently extended his researches among the oolites northwards to the Cotteswold Hills, and showed that the stone-tiles or "Slates" of Sevenhampton, in Gloucestershire, were equivalent to the Stonesfield Slate at the base of the Great Oolite, and were not on the horizon of the Forest Marble, as had been supposed.

The age of the Stonesfield Slate, near Oxford, which had been worked since the time of the Roman occupation for its stone-tiles, had become a matter of considerable interest a few years previously, on account of the reported discovery

in it of mammalian remains. The discovery was startling, because no mammal had hitherto been obtained in strata older than the Tertiary, and to find remains in a formation of such antiquity as the Great Oolite aroused keen interest and much incredulity.

The specimen was found by W. J. Broderip, and recognised as mammalian in 1818 by Cuvier, who referred it to the genus *Didelphis*. It was not, however, until 1825 that general excitement appears to have been aroused. The identification was supported by Buckland, and accepted in France by Valenciennes and by Constant Prevost; but the latter questioned the geological age of the stratum. The position of the Stonesfield Slate, at the base of the Great Oolite, was verified on independent grounds by Fitton in 1828; and then the zoological affinities of the specimen were questioned by Agassiz, de Blainville, and R. E. Grant. The controversy was finally set at rest by Owen in 1838, when he named the genus *Phascolotherium*.

It is interesting to know that a specimen of mammal from Stonesfield was obtained about the year 1764 by Joshua Platt; it came under the notice of John Phillips, and was placed in the York Museum in 1828. This fossil is now known as *Amphilestes Broderipi*.

Among gigantic dinosaurs, some of which attained a length of about 30 feet, the *Megalo-*

sauros, from the Great Oolite of Stonesfield, was described by Buckland in 1824.


The *Teleosaurus*, a crocodilian, obtained by J. A. EUDES-DESLONGCHAMPS (1794-1867) from a quarry in the famous building-stone of Caen, in Normandy, approximately the same age as the Stonesfield Beds, was described by Geoffroy-St.-Hilaire in 1825. Deslongchamps worked zealously at the remains of these saurians, and prepared a memoir which was completed by his son Eugène.

Among mammals, the famous *Dinotherium giganteum*, from the Miocene strata of Eppelsheim, near Worms, was described in 1829 by J. J. Kaup, who was Inspector of the "Grand-Ducal Cabinet of Natural History" at Darmstadt.

W. H. FITTON, M.D. (1780-1861), whose name has been mentioned in connection with the age of the Stonesfield Slate, at one time practised as a medical man, but ultimately devoted his attention wholly to geological science. In 1824 he commenced to publish his researches on the upper Jurassic and Cretaceous strata, the full results of which were embodied in his classic memoir, written after prolonged study and deliberation, and published in 1836, *Observations on some of the Strata between the Chalk and the Oxford Oolite, in the Southeast of England*. Fitton was one of the great masters of Stratigraphical Geology, and to him and to Mantell

was mainly due the determination of the sequence and subdivisions of the Cretaceous strata.

G. A. Mantell (1790–1852), who during a great part of his career was occupied as a surgeon with a large practice in Sussex, devoted his leisure hours to the collection of fossils, and formed an extensive museum at Lewes. This was afterwards removed to Brighton, and, as remarked by Lyell, it was “a monument of original research and talent.” In 1822 Mantell published *The Fossils of the South Downs; or, Illustrations of the Geology of Sussex*, a quarto work of permanent value. In the same year he obtained the tooth of a new saurian from a quarry in the Wealden strata near Cuckfield, and, as the specimen was eventually determined by him, in 1825, to most nearly resemble a tooth of the modern lizard *Iguana*, he named the fossil the *Iguanodon*. Subsequently he obtained many other vertebrate remains, and in 1827 published another work, *Illustrations of the Geology of Sussex; with figures and descriptions of the Fossils of Tilgate Forest*. Referring to that volume, Mantell remarked in 1851 that, although it had been eulogised by Cuvier, “not fifty copies of it were sold.” In 1832 Mantell obtained another new reptile, which he named the *Hylæosaurus*, or “Forest Lizard,” from its occurrence at Cuckfield, in the somewhat vague area of Tilgate Forest. Remains of *Iguanodon*



were also found in some abundance in the Kentish rag (Lower Greensand) of Maidstone. At the suggestion of P. J. Martin, a medical man residing at Pulborough, and author of *A Geological Memoir of Western Sussex*, 1828, Mantell introduced the name Wealden formation for the Weald clay and Hastings Beds, which he had determined to be of fluviatile origin.

Fitton did more to elucidate the sequence and relations of the strata between the Wealden and the Chalk—the Lower Greensand, Gault, and Upper Greensand—the last-named formation being of special interest to collectors of fossils on account of the beautiful silicified mollusca found in the scythe-stone pits of Blackdown, in Devonshire.

Among researches carried on in other parts of Europe and America, mention may be made of the work in France of Marcel de Serres on the bone-caverns of Lunel-Viel, Hérault (1826), on the Tertiary Strata and fossils (1829), and on artesian wells (1830); while Adolphe Brongniart wrote on the history of fossil plants (1828 and later). In Sweden Nilsson described some of the Cretaceous fossils in his *Petrifacta Suecana* (1827), in Germany Von Zieten dealt with the fossils of Wurtemberg (1830), Pander wrote on the geology of Russia (1830 and later), and Conrad described the Tertiary mollusca of the United States (1832-3).

CHAPTER IV

THE PRINCIPLES OF GEOLOGY

THE years 1830 to 1833 were marked by the publication of the first edition, in three volumes, of Lyell's *Principles of Geology, being an attempt to explain the former changes of the Earth's surface by reference to causes now in action*, a work which, as Conybeare observed, was "in itself sufficiently important to mark almost a new æra in the progress of our science." It was not that the leading principle was new; some of the earliest philosophers had pointed to modern changes of the earth and its inhabitants as illustrative of the past; and since the enunciation of the views of Hutton it was admitted by the foremost geologists that the phenomena of their science were to be interpreted by a study of the physical causes in operation.

In Germany the principles of geology were very clearly explained by Von Hoff, of Gotha, in 1822 and subsequent years, in a work wherein the natural changes in progress on the earth's

surface were somewhat fully treated. The author has been described as an original thinker of great merit, but his views were derived from an exhaustive study of the literature; and it was as a philosophical historian rather than as a geologist that he influenced the progress of the science.¹

CHARLES LYELL (1797-1875), who was born at Kinnordy, in Forfarshire, was educated at Oxford, and thither he went with some interest in geology, which was developed by the fascinating lectures of Buckland. Intending at one period to adopt the Law as a profession, he studied the subject, and was called to the Bar in 1825. The training, no doubt, was of essential importance to him; but his interests were gradually concentrated on geology, and although he accepted in 1831 the chair of geology at King's College, London, he had sufficient means to be independent, and soon abandoned professorial work. In 1825 he commenced to contribute papers on geology, and in the following year made important additions to the knowledge of the Tertiary strata of Hampshire and Dorset. By extended travel and personal observation, and by a study of the publications on the subject, he qualified himself for the great task which may

¹ See review of *Karl Ernst Adolf von Hoff, der Bahnbrecher moderner Geologie*, by Dr. Otto Reich, in *Nature*, June 8, 1905.

be said to have dominated his life—the illustration of the *Principles of Geology*. The chief merit of this work from its inception was that it was written by a keen geologist with wide experience and sound judgment. Facts relating to physical phenomena, to zoölogy and botany, such as would throw light on geological problems, were gathered from all parts of the world, and from observers and philosophers of all times. Thus, by wealth of illustration and clear reasoning, it was made plain to the general reader, as well as to the geologist, that the Physical Geography of the present day was but a portion of the latest chapter of geological history, separated from the past by no universal break in the continuity of life or other natural phenomena.

The *Principles of Geology* was a far-reaching work in its discussion of various problems; but the first volume, in particular, aroused a good deal of hostile criticism from some of the leading geologists. They were opposed to the notion that present conditions could be taken to exemplify all that had happened in the past; the physical causes were the same in kind, but, as Conybeare remarked, and he was supported by Sedgwick, these causes “may have been modified as to the degree and intensity of their action by the varying conditions under which they may have operated at different periods.” Lyell,

when he issued his third volume in 1833, denied that he advocated that "the existing causes of change have operated with absolute uniformity from all eternity"; nevertheless, his doctrine of Uniformity was somewhat extreme, and it was undoubtedly taken in too restricted a sense by some of his followers. Thus, many years later, in 1880, A. C. Ramsay expressed his belief "that from the Laurentian [Archæan] epoch down to the present day all the physical events in the history of the earth have varied neither in kind nor in intensity from those of which we now have experience." A more just view was taken, in 1893, by Dr. J. J. H. Teall, who remarked that "All geologists will admit that denudation and deposition were taking place in pre-Cambrian times, under chemical and physical conditions very similar to, if not identical with, those of the present day."

On the other hand, Prestwich, in 1886, observed that Non-uniformity does not "involve any questions respecting uniformity of law, but, only those respecting uniformity of action"; and he held that there was evidence "that the physical forces were more active and energetic in geological periods than at present."

There is, of course, room for divergence of opinion with regard to the last paragraph, but a modified Uniformitarian view may be said to dominate at the present day. As Whewell

remarked in 1839: "We know causes only by their effects"; and, while admitting that much could be done in the course of time, yet force must not be neglected.

Volcanic energy has been potent in our times not only along the Italian shores, but at Krakatoa, Mont Pelée in Martinique, and at St. Vincent. Earthquakes and seaquakes have produced devastation. Great floods have occurred, though their effects have to some extent been mitigated by human action; but the potency of Diluvial action, at one time discredited by many in Britain, receives support in connection with the floodwaters of the Glacial period.

The great work of Lyell may be said to have shown the fallacy of reasoning of the older school of geological speculators known as the Catastrophists. It is interesting to note that the title of the book was in after years modified from that given in the first edition (see *ante*, p. 96). In the eleventh edition, the last personally revised by Lyell in 1872, the title is *Principles of Geology, or the Modern Changes of the Earth and its Inhabitants Considered as Illustrative of Geology*; and this is not so rigidly uniformitarian as the earlier title.

When the first edition of Lyell's *Principles* was published (vol. iii., p. 369), the order of superposition of the principal Sedimentary Deposits or Formations in Europe was stated as follows:

Recent Period

Tertiary Period {
 Newer Pliocene
 Older Pliocene
 Miocene
 Eocene

Secondary Period	Cretaceous	Maestricht Beds
		Chalk
		Upper Greensand
		Gault
	Wealden	Lower Greensand
		Weald Clay
	Oolite or Jura Limestone Group	Hastings Sands
		Purbeck Beds
		Portland Beds
		Kimeridge Clay
Coral Rag		
Oxford Clay		
Cornbrash		
Lias	Forest Marble	
	Great Oolite	
New Red Sandstone Group	Inferior Oolite	
	Lias	
	Keuper or Variegated Marls	
	Muschelkalk	
	Variegated Sandstone	
Carboniferous Group	Magnesian Limestone	
	Red Conglomerate	
	Coal Measures	
	Mountain Limestone	
	Old Red Sandstone	
	Grauwacke and Transition Limestone	

The Primary formations were then explained by Lyell to be "those, whether stratified or unstratified, which are older than the carboniferous deposits." The term primary had been substituted for that of primitive, and was used "as simply expressing the fact, that the crystalline rocks, as a mass, were older than the *secondary*, or those which are unequivocally of a mechanical origin and contain organic remains."

Lyell in 1833 remarked of the stratified rocks that "the order of succession was never inverted," the effects of great overfolding and displacement being then unknown. He recognised the fact that "there were granites of different ages, and that, instead of forming in all cases the oldest part of the earth's crust, as had at first been supposed, the granites were often of comparatively recent origin, sometimes newer than the stratified rocks which covered them."

With regard to the Transition formations Lyell pointed out that there had been discovered "in many districts, certain members of the so-called primitive series, either alternating with or passing by intermediate gradations into rocks of a decidedly mechanical origin, containing traces of organic remains." By the aid of fossils "the groups first called transition were at length identified with rocks, in other countries, which had undergone much less alteration,

and wherein shells and zoöphytes [corals] were abundant. The term transition, however, was still retained, although no longer applicable in its original signification. It was now made to depend on the identity of certain species of organised fossils; yet reliance on mineral peculiarities was not fairly abandoned, as constituting part of the characters of the group." He remarked, however, quite rightly that the state of mineral character "ought never to have been made the basis of a chronological division of rocks."

It is surprising that the Carboniferous Group was used in so extended a sense as to include "the coal-measures, the mountain limestone, the old red sandstone, the transition limestone, the coarse slates and slaty sandstones called graywacke¹ by some writers, and other associated rocks." Lyell, however, stated that "The mountain and transition limestones of the English geologists contain many of the same species of shells in common," that coal "alternates in some districts with mountain limestone," and that "some of the rocks termed graywacke in Germany are connected by their fossils with the mountain limestone."

De la Beche, indeed, in his *Geological Manual*, published in 1831, and spoken of by Conybeare

¹ This word is spelt also greywacke and grauwacke by Lyell in different pages of his *Principles*, ed. i.

in 1832 as the best work of its kind which had yet appeared in our country, regarded the Old Red Sandstone as the base of the Carboniferous Group, but ranged beneath it the following groups:

Grauwacke Group	{ Grauwacke, thick-bedded, and schistose, sometimes red; Grauwacke limestones; Grauwacke clay slates, etc.
Lowest Fossiliferous Group	{ Various slates, frequently mixed with stratified compounds resembling those of the unstratified rocks.
Inferior Stratified or Non-Fossiliferous Rocks	{ Various schistose rocks, gneiss, etc. No determinate order of superposition.

Thus the stratigraphical sequence and organic remains of the great Palæozoic formations beneath the Old Red Sandstone had yet to be elucidated.

The succession given by Lyell above the Grauwacke and Transition Limestone is practically that adopted at the present day in Britain, although the names of many of the formations have naturally been modified abroad, as their chronological limits did not coincide with the divisions in this country.

The increase in the proportion of recent species of mollusca in passing from the older to the newer Tertiary strata, in 1829 attracted the attention of DESHAYES (1797-1875), who had been engaged in researches on the fossil mollusca of the Paris Basin, and had published in 1824 two volumes entitled *Description des Coquilles Fossiles des Environs de Paris*. The third volume of the work by Deshayes was not published until 1857, owing to the fact, mentioned by Lyell, that "Deshayes, now the strongest fossil conchologist in Europe, has lost so seriously by his fine work on the shells of the Paris basin, that he is not only obliged to stop, so miserably is it encouraged, but his circumstances are injured for a time by it."¹

About the same date, in 1829, Lyell had arrived at similar conclusions to those of Deshayes from purely geological considerations; and he subdivided the Tertiary epoch, so far as possible according to the percentage of recent mollusca, as follows²:

Recent

Pliocene—signifying a major proportion of recent mollusca

Miocene " a minor " " " "

Eocene " the dawn of living species

These names have been permanently adopted,

¹ *Life, etc., of Lyell*, 1881, vol. i., pp. 246, 307.


² *Principles of Geology*, vol. iii., 1833, pp. 52-56.

although the test of the actual percentage of recent species among the extinct forms is no longer considered; and, in fact, other divisions of Oligocene and Pleistocene have been introduced.

In Lyell's general Table (of 1833) it will be seen that the minor subdivisions of the Tertiary strata, and the grouping of the newer deposits, all classed as Recent, had yet to be determined. De la Beche in 1831 had, however, indicated in his Table the following divisions, in descending order, above the Tertiary or Supercretaceous Group:

Modern Group	{	Detritus of various kinds produced by causes now in action; Coral island, Travertino, etc.
Erratic Block Group		Transported boulders and blocks; gravels on hills and plains, apparently produced by greater forces than those now in action.

Lyell remarked on the older views of the universality of formations, and pointed out how the characters of the strata changed, although "many rocks retain the same homogeneous structure and composition, through considerable areas, and frequently, after a change of mineral character, preserve their new peculiarities



throughout another tract of great extent." Proofs of contemporaneous origin were to be derived from organic remains; but due regard must be paid to zoölogical provinces, as distinct organic remains may be embedded in contemporaneous deposits—a caution not unneeded at the present day.

Conybeare in 1832 remarked "that a much nearer approximation may be observed between the fossil animals and vegetables of the old and new continents than between those occupying them at the actual period." He referred to the groups of specimens obtained from Dudley and from Melville Island, and also to the types indicative of a tropical temperature, that are found within the arctic circle. He was led to conclude that, up to the time of deposition of the Carboniferous rocks, "the surface of the globe was still chiefly oceanic, interspersed only with scattered groups of islands, having a tropical temperature."


Lyell entered into a full discussion regarding genera and species, of the question "Whether Species have a real existence in Nature?" and of the arguments in favour of the theory of transmutation of species. He admitted that "there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly according to the species . . . but the

mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the permanent specific character." He dealt also with the geographical distribution, the appearance of new species, and the doctrine of centres of creation. He pointed out "that the hypothesis of the gradual extinction of certain animals and plants, and the successive introduction of new species, was quite consistent with all that is known of the existing economy of the animate world."

Sedgwick in 1831 went so far as to recognise "that there has been a progressive development of organic structure subservient to the purposes of life," and he referred to the "intelligence contriving means adapted to an end, but at successive times and periods contriving a change of mechanism adapted to a change in external conditions."

Thus we find that at the time of publication of the first edition of Lyell's *Principles* many questions that are still under debate were carefully considered in accordance with the facts then known.

The full scope of geology as a science came to be realised after the publication of Lyell's *Principles* in 1833. Then for a period of forty years Lyell may justly be considered to have taken the leading position in the world as the exponent of geological processes, and the



chronicler of the advances made to our knowledge of the structure and history of the earth.

Other distinguished geologists at home and abroad aided the progress of the science by the preparation of manuals. Among those in Britain were De la Beche, Buckland, John Phillips, and Mantell; in France, Omalius d'Halloy (1783-1875), Vicomte d'Archiac, and d'Orbigny; in Germany, Carl Vogt and C. F. Naumann; in Switzerland, Bernhard Studer; and in Italy, Antonio Stoppani.

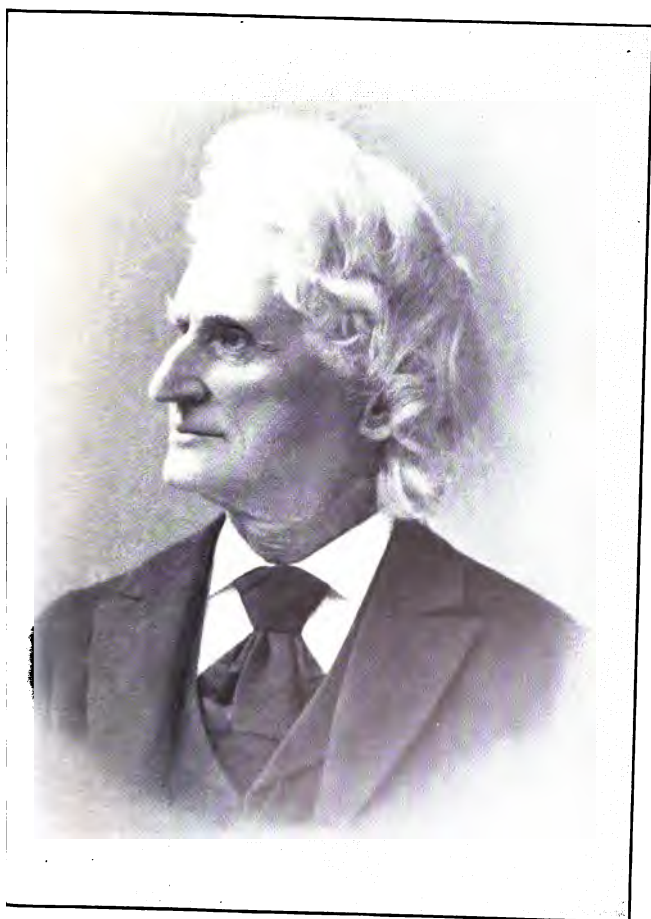
To JAMES DWIGHT DANA (1813-1895), who for many years was Professor, first of Natural History and afterwards of Geology and Mineralogy in Yale College (now the University) in Connecticut, we owe the famous *System of Mineralogy*, issued in 1837. This volume became the authoritative work of reference in all parts of the world, and reached a sixth edition in 1892, the author in later years being assisted by his son, Professor E. S. Dana. In 1863 was published the first edition of Dana's *Manual of Geology; treating of the Principles of the Science, with special reference to American Geological History*—a work which likewise became a standard authority, the fourth edition being published in 1895, when the author was in his eighty-second year. Regarded as "the foremost geologist of America and one of the fore-

most of the world,"¹ Dana was also a Naturalist in the highest sense, as exemplified by his researches on *Corals and Coral Islands*, commenced in 1838, the results of which were embodied in a separate volume in 1872.

Geology, which in early days was considered mainly from the point of view of cosmogony, and later as a branch of mineralogy, finally became more intimately linked with other subjects. As a separate science, its purpose was to investigate the history of the organic as well as inorganic changes that have taken place on the earth's surface; but its limits, indeed, were so difficult to define that Sir William Flower on one occasion, and with scant respect, spoke of geology as a "heterogeneous compound of sciences." Regarded as the physical geography of past ages, geology to a certain extent had to deal with all the subjects that were usually included under that heading, from astronomy to zoölogy and botany.

In attempting to sketch the history of progress in the fourth and later decades of the nineteenth century and afterwards, it will be best to note, as far as space permits, some of the leading discoveries and advances made in the separate branches of geology.

¹ G. P. Merrill (1906), p. 694.



JAMES DWIGHT DANA.
From a photograph.

CHAPTER V

LOCAL AND OFFICIAL GEOLOGICAL SURVEYS AND ECONOMIC GEOLOGY

MENTION has already been made of some of the early geological maps, the scale of which was comparatively small. When larger topographic maps were constructed in different countries the progress of geology was aided in a marked degree. The boundaries of the different rock-formations and the faults or main lines of dislocation could be represented on the maps; and thus, with the aid of longitudinal sections, the geological structure of the land, its influence on the scenery and in reference to economic questions, could be made manifest.

Fortunate it was that in the early part of the nineteenth century the Superintendent of the Trigonometrical Survey of Britain, Colonel T. F. Colby,¹ took great interest in geology. He

¹ Colonel, afterwards Major-General, Colby was given the title of Director-General in 1820, after having performed the duties of Superintendent of the Survey since 1809.

Geological Surveys—Economic Geology 113

had become a member of the Geological Society of London in 1814, and he encouraged the officers under his command to note the "mineral changes" in the areas which they surveyed.

As early as 1814, MacCulloch was appointed Geologist to the Trigonometrical Survey, apparently as a consulting geologist, and in 1826 he was instructed to prepare a geological map of Scotland. This was long before the official topographical survey extended over that country, and the work was laid down on Arrowsmith's map, and was not published until 1836, after MacCulloch's death.¹

At the commencement of the Trigonometrical Survey in Ireland, Colonel Colby expressed his opinion that the work "should be considered a foundation for Statistical, Antiquarian, and Geological Surveys," and attention was given to these subjects about the year 1830 by Captain J. W. Pringle. The geological work was afterwards carried on by J. E. Portlock (1794-1864), a Royal Engineer (ultimately Major-General), who had seen active military service in Canada. He joined the Irish Staff in 1824, took a keen interest in geology, and in 1832 commenced the formation of the department which, five years later, was definitely organised as the geological branch of the Trigonometrical Survey in Ireland.

¹ See Judd, *Geol. Mag.*, 1898, p. 145.

Meanwhile, in England De la Beche had for some years been occupied in the self-imposed but congenial task of making a geological survey of parts of Devon and Dorset on the one-inch Ordnance maps, in a region familiar to him from his early researches in the neighbourhood of Lyme Regis. His field labours came under the notice of Colonel Colby in 1832, with the result that De la Beche was officially appointed to affix geological colours to the map of the county of Devon, with adjacent portions of Somerset, Dorset, and Cornwall. This undertaking, which included eight sheets of the Ordnance Survey, was duly completed, and published by the Board of Ordnance in 1834 and 1835.¹

In 1835 Lyell (who was then President of the Geological Society of London), together with Buckland and Sedgwick, represented to the Board the great public advantage that would result from a systematic geological survey, and this led to the appointment of De la Beche as Director of the Ordnance Geological Survey, then established as a branch of the Trigonometrical Survey of Great Britain.

Although the earliest State geological survey appears to have been commenced in North America, it is generally admitted that the first official or government geological survey of a

¹ H. B. Woodward: "Summary of Progress," *Geol. Survey* for 1907-1908, p. 158.

Geological Surveys—Economic Geology 115

country was instituted through the enthusiastic personal labours of De la Beche. His methods were largely followed in other countries, and thus was created one of the most interesting and attractive of scientific professions.

It is noteworthy that in India, as early as 1818, a geologist was appointed to the Trigonometrical Survey through the Honourable East India Company. The first report of the Geological Survey of India was that issued by Dr. John McClelland for 1848-49; but the department was not thoroughly organised until it came under the superintendence, in 1851, of Thomas Oldham (1816-1878), formerly Director of the Irish branch of the Geological Survey, who, "on his arrival in Calcutta, found the Geological Survey represented in the capital of India by a room, a box, and a messenger."¹

It should be mentioned that, when carrying on the Geological Survey in South Wales, De la Beche received much honorary assistance from WILLIAM E. LOGAN (1798-1875), a keen geologist who had surveyed with great accuracy the coal-crops and limits of the strata over a large area in the neighbourhood of Swansea. Logan, in 1840, discovered the rootlets of *Stigmaria* in the underclay beneath seams of coal, and suggested that the deposit was the soil on which the

¹ "Fifty Years of Geological Survey in India," *Nature*, May 31, 1900, p. 105.

plants grew. In 1842 he was appointed the first Director of the Geological Survey of Canada, a post especially appropriate, as he had been born at Montreal.

Austro-Hungary instituted a Geological Survey in 1849, under W. von Haidinger, who was followed by F. Ritter von Hauer; and a complete geological map of the country was issued during the years 1867-71.

In most countries independent geological maps were prepared before official geological surveys were definitely organised.¹ Thus the famous geological map of France by ÉLIE DE BEAUMONT and P. A. DUFRÉNOY (1792-1857) was prepared under the instructions of Brochant de Villiers (1772-1840), Professor of Geology and Mineralogy in the *École des Mines*. Together the three geologists came to England in 1822 to study the succession of strata; and their map of France, commenced in 1823, was issued, with accompanying text in two volumes, during the years 1840-48.

The most important of the general geological maps of Germany was that of HEINRICH VON DECHEN (1800-1889), published in 1869. The author, one of the more distinguished of German geologists, also published (1855-1882) a large scale map of Rhenish Prussia and Westphalia.

¹ See W. Topley (1885).

Geological Surveys—Economic Geology 117

Among other maps, that of Bavaria was issued in 1858 by C. W. von Gümbel (1820–1898). Systematic geological surveys were established at later dates in Germany largely through recognition of the value of Von Dechen's maps.

In Russia various geological maps of departments were published from time to time, much work being carried out by Abich (1806–1886), Von Eichwald (1795–1876), and others. In 1841 General von Helmersen (1803–1885) published a geological map of Russia in Europe; and in 1845 there appeared the great work by Murchison, De Verneuil, and Von Keyserling on *The Geology of Russia in Europe and the Ural Mountains*, with accompanying maps. Finland commenced a geological survey in 1865; Norway and Sweden were, however, in advance, their surveys having been begun in 1858 by Kjerulf, Dahll, and Erdmann. In Switzerland work was organised in 1859, under the presidency of the illustrious geologist, BERNHARD STUDER (1794–1887), who, with Escher von der Linth, had previously published a geological map of the country.

Of Belgium a general geological map was prepared by order of the Government, during the years 1836–54, by ANDRÉ H. DUMONT (1809–1857), and published in 1854. Dumont was likewise distinguished as the author of the first geological map of Europe. A systematic survey

of Belgium was subsequently established under the direction of E. Dupont.

In Italy the geological survey, though commenced in 1868, was not systematically organised until 1877, under the direction of F. Giordano. Among the distinguished geologists of that country mention should be made of PAOLO SAVI (1798-1871), who was born at Pisa. A man of great attainments as a naturalist, he lectured on geology and zoölogy, and rendered the collections in the University Museum among the finest in Europe. He carried out researches on various geological subjects: on the more ancient rocks, on the metamorphic origin of the Carrara marble, on Miocene lignites, the iron-ores of Elba, etc. As remarked by Prestwich, he contributed largely to the revival of science in Italy, and was regarded as the "Father of Italian Geology." He was succeeded in the professorship of geology by Meneghini (1811-1889), with whom in 1850 and 1851 he published works on the Stratigraphy and Palæontology of Tuscany.

In the United States geological surveys were commenced at an early date in the last century. In New York systematic work was first carried on by Amos Eaton in 1824, and subsequently by James Hall, Ebenezer Emmons, Timothy Conrad, and others. Nevertheless, "To Massachusetts credit must be given for the first geo-

Geological Surveys—Economic Geology 119

logical survey made at the expense of the State, the same being begun under the direction of [the] Rev. Edward Hitchcock in 1830."¹ Subsequently W. B. and H. D. Rogers, Richard Dale Owen, Jules Marcou, J. S. Newberry, and others, took leading parts in various State surveys.

The first Government surveys (military, topographic, and geological) were organised by Clarence King, F. V. Hayden, J. W. Powell, and G. M. Wheeler; and the present United States Geological Survey followed on their discontinuance in 1879. The reports of the various explorations and surveys, though voluminous, are rich in facts and explanations of geological interest and of economic importance.

Jules Marcou (1824–1898), who was born in France, spent many years of his life in America, and prepared in 1861 the first important geological map of the world, a second edition of which was issued in 1875.


Japan has for many years given attention to questions of practical as well as purely scientific geology. The Geological Survey of the Empire issued colour-printed geological maps before they were published officially in Britain; and a

¹ See Merrill (1906), p. 266; Address to Geological Society of Washington, by C. D. Walcott, 1894, 1895; also The United States Geological Survey, *Bulletin*, No. 227, 1904.

general geological map of Japan, on the scale of 1 : 1,000,000, with descriptive text, was published in 1900. Korea has been specially studied by Professor Bunjiro Kotô.

In South Africa our early knowledge of the geology was due to the enthusiastic labours of private individuals. The pioneer and "Father of South African Geology" was ANDREW G. BAIN (1797-1864), who left Scotland in 1820 for Cape Colony, became a surveyor of roads, and was, in the course of his work, attracted to the subject of geology. He discovered in the Karroo beds remains of *Dicynodon*, which were described by Owen; and he published, in 1856, the first geological map of South Africa.

Another enthusiastic worker, Dr. W. Guybon Atherstone (1813-1898), was the first to discover diamonds in Cape Colony; while G. W. Stow (1822-1882), who emigrated to South Africa in 1843, had a remarkable career. Devoted to researches in geology and ethnology, author of an important report on the geology of Griqualand West, and discoverer of the Vereeniging coal-field, he yet had a terrible "struggle for existence." Beginning life as a Church teacher and catechist, he subsequently took up arms in one of the Kaffir wars, and was then engaged successively in farming, as a bookkeeper, broker and commission agent, manager of a



Geological Surveys—Economic Geology 121

general store, wine merchant, diamond dealer, and auctioneer.¹

In Australia the most prominent geological pioneer was the Rev. W. B. CLARKE (1798–1878), who was born in Suffolk and educated at Cambridge. After publishing important papers on the geology of Suffolk and Dorset, he settled in 1839 in New South Wales. Devoting his attention to geology, he was fortunate in 1841 in finding gold for the first time *in situ*; and in 1844, in ignorance of this fact, its occurrence in Australia was predicted by Murchison, who, from an examination of rocks collected by Count Strzelecki, perceived a great similarity between the specimens and the gold-bearing rocks of the Ural Mountains. Nevertheless, the first practical discovery of gold in New South Wales was made in 1851 by E. H. Hargraves, and it was not until that year that the rush to the Australian “Ophir” took place. Clarke, who identified Silurian rocks, and proved the Carboniferous age of the coal-bearing strata of New South Wales, has been justly regarded as the “Father of Australian Geology.”

Sir Frederick McCoy (1823–1899), who had worked with Sedgwick on the Lower Palæozoic fossils of England and Wales, and had written on the Carboniferous and Silurian rocks of

¹ See R. B. Young (1908); also *Geology of Cape Colony*, by A. W. Rogers and A. L. Du Toit (1909).

Ireland, was in 1854 appointed Professor of Natural Science in the University of Melbourne, and from that date devoted his energies mainly to the palæontology of Victoria.

New Zealand has had the benefit of many able geologists. Sir James Hector (1834-1907) was in 1861 appointed Geologist of Otago, and four years later Director of the Geological Survey of New Zealand. Meanwhile F. von Hochstetter (1829-1884), who had been engaged on the Geological Survey of Bohemia, visited New Zealand and prepared a Geological and Topographical Atlas of the country, which was published, with descriptive text, in 1864. Julius von Haast (1824-1887), who had been educated at Bonn, arrived in New Zealand about the same time as Von Hochstetter, and, after rendering him assistance, undertook official geological surveys of Nelson and Canterbury. Another geologist and naturalist, F. W. Hutton (1836-1905), after receiving a military education and serving in the Crimea and in India during the Mutiny, settled in New Zealand in 1866. He was occupied for a short time in the geological survey at Wellington, and ultimately became Professor of Biology and Geology in the University of New Zealand at Christchurch.¹

¹ A capital summary of what is known of "The Geology of New Zealand" has been published by Professor James Park (1910).

Geological Surveys—Economic Geology 123

Although the work is carried out on scientific principles, the justification for the establishment of Geological Surveys has been in the application of science to useful purposes. The questions that arise in this connection may in themselves be as full of interest as those which deal solely with what is termed pure science; indeed, Mr. C. D. Walcott has remarked: "Someone has said that utility is the bane of science, but a greater man has written that philosophy is never more exalted than when she stoops to minister to humanity."¹

The investigations of the United States Geological Survey on the iron-ores of the Lake Superior region, the various reports on other metalliferous deposits, the work of the Hydrographic division in gauging streams and investigating underground as well as surface sources of water supply, may be mentioned as works of immense importance.


Practical men have not always shown wisdom in engaging in expensive and speculative enterprises without previously obtaining scientific information. Thus the occurrence of black shales and lignite have given rise to the supposition that Coal-measures were present, and numbers of fruitless trials have been made in Britain in shales older and in shales younger than the

¹ Address to Geol. Soc., Washington, in 1894.

Coal-measures. Within the last ten years there have been reports of the discovery of "coal" in Sussex (where lignite occurs in the Wealden strata), while a trial boring more than 1300 feet deep at Lyme Regis was commenced in the Lower Lias in the hopes of reaching Coal-measures at a depth of less than 600 feet. It was known that in the Bristol district coal was worked beneath a thin covering of Red rocks and Lias; but the ignorance of the great thickness of New Red rocks in South Devon was inexcusable. As a matter of fact, the boring did not reach the base of the Keuper marls.

Samuel Sharp, in referring in 1871 to a futile search for coal near Northampton, remarked that one prominent man of means who supported the undertaking declared his utter lack of faith in geologists, and based his belief on the supposition "that where God has sent iron-ore he has also sent coal to smelt it."

The question of the possible underground extension of Coal-measures in the south-east of England, hinted at by De la Beche and others in earlier days, was first discussed in detail by GODWIN-AUSTEN (1808-1884), one of the most philosophical of British geologists. In 1855 he came to the conclusion that there might be a continuation of the Franco-Belgian coal-field beneath the Chalk and Tertiary strata along the line of the Thames Valley.



Geological Surveys—Economic Geology 125

A trial boring for coal at Dover was commenced in 1886, and four years later coal was proved at a depth of 1113 feet.¹ Subsequent borings have proved that Coal-measures occur elsewhere beneath Cretaceous and Jurassic rocks to the north of Dover; but the occurrence of Coal-measures along the Thames Valley below London is rendered improbable by the discovery at Cliffe, east of Gravesend, of Silurian rocks beneath the Cretaceous strata, as well as by the results of deep borings under London and in Essex.

¹ W. B. Dawkins: *Trans. Manchester Geol. Soc.*, xxii., 1894; *Journ. Soc. Arts*, lv., 1907, p. 450.

CHAPTER VI

THE ELUCIDATION OF THE OLDER GEOLOGICAL SYSTEMS, WITH REMARKS ON THE HISTORY OF THE NEWER SYSTEMS

THE sequence of the rock-formations and organic remains beneath the Old Red Sandstone had not been established in any country when the third volume of Lyell's *Principles* was published in 1833; nor had order been determined in the great series of Greywacke grits, slates, and limestones that occur in West Somerset, Devon, and Cornwall, and are now known to have equivalents in many districts abroad.

The task of unravelling the main structure in the mountainous and hilly regions of the Lake District, of much of Wales, and of the southwest of England was accomplished, after prolonged toil, by two of the great masters—Sedgwick and Murchison. To them we owe the determination of the successive groups of strata and organic remains whereby they founded the Cambrian and Silurian systems, and finally

Older and Newer Systems Elucidated 137

who worked out in detail the numerous zones characterised especially by graptolites.

Through the work also of J. G. O. LINNARSSON (1841-1881) on the Lower Palæozoic formations of Sweden, as pointed out by Professor Lapworth, the sequence established among these older rocks and their organic remains had come to be regarded "as the most reliable and authoritative standard of reference yet defined." Angelin (1805-1876) had previously determined the successive forms of trilobites that characterise the Swedish strata; while Linnarsson dealt more particularly with the graptolites. In the course of his work he had to encounter many difficulties, partly from the fact that "In Southern Sweden the strata are of such remarkable tenuity that the fossils peculiar to several subformations in the vertical series lie in close proximity, and, unless collected inch by inch, *in situ*, are certain to become intermixed in the collection." In 1876 Linnarsson contributed a paper on the "Vertical Range of the Chief Types of Graptolites in Sweden," and it is specially interesting to know that the succession corresponded precisely with that determined by Professor Lapworth in Britain. Ultimately their separate labours "placed it absolutely beyond question that the grander Graptolitic zones recognisable among the Lower Palæozoic rocks of this country have

also the Devonian—grand systems, the names of which have been adopted for equivalent formations in all quarters of the world.

As early as 1822 Sedgwick had commenced work among the older rocks of the Lake District, where the three principal formations and their general distribution had been observed in 1820 by a humble, but acute and zealous, worker, Jonathan Otley, of whom Sedgwick spoke in the highest terms. These three groups—the Skiddaw Slate, the Green Slate and Porphyry (Borrowdale series), and especially the Greywacke series—were studied in detail by Sedgwick, who determined their relationships and their main subdivisions; but it was not until 1845, after the Cambrian and Silurian systems had been established in Wales and the border counties, that he was able to fully interpret his succession in the Lake District. In those early days geologists usually wore tall hats; and Sedgwick has been described as being attired generally in a white one, and riding on horseback, with saddle-bags for his specimens and a miner's boy *en croupe*.

It was in 1831 that Sedgwick and Murchison began their work among the older rocks of Wales and the English border counties. Sedgwick started in the more mountainous and complicated region of Carnarvonshire, gradually extending his investigations through the

counties of Merioneth, Montgomery, and Denbigh. The region, as he remarked, was "little more than a *terra incognita*," composed of slates, grits, subordinate limestones, and volcanic beds, much folded, faulted, and altered by igneous intrusions. Out of these tangled masses, by dint of arduous labour, he succeeded in determining the main rock-groups, and in ascertaining their order of succession from the older slates and grits of Bangor, Llanberis, and Harlech to the fossiliferous limestones of Bala.

Murchison commenced his studies between Hay, in Herefordshire, and Builth, in Radnorshire, working eventually through the counties of Shropshire, Brecknock, and Carmarthen to the north of the great coal-field of South Wales. Gifted with what has been termed "a good eye for the country," he readily grasped the relations between the strata and the physical features; and in the well-defined scarps of Wenlock Edge and the country southward to Ludlow and Aymestry he soon determined an orderly succession, and marked out the main groups in the region of Siluria. In this work, as Murchison cordially acknowledged, he was greatly aided by the Rev. T. T. Lewis, Vicar of Aymestry, and by other local geologists who had diligently collected fossils. Thus were established on a firm basis the following stratigraphical groups, which were distinguished by

characteristic fossils and classed as Upper Silurian:

Ludlow	{ Upper Ludlow Rock Aymestry Limestone Lower Ludlow Rock
Wenlock	{ Wenlock Limestone Wenlock Shale

Beneath the Wenlock Beds Murchison placed in his Lower Silurian the Caradoc Sandstone, and then the Llandeilo Flags, which he regarded as the base of the system; but, as remarked by Professor Lapworth, "he failed signally, however, in strictly and correctly defining his lower groups, and in correlating some of his most typical beds."

The names CAMBRIAN and SILURIAN were introduced by Sedgwick and Murchison in 1835. It was then thought by both geologists that the Upper Cambrian of Sedgwick, with the Bala limestone on top, passed beneath the Llandeilo Flags of Murchison's Lower Silurian. In 1838 it was perceived by Sedgwick that many of his Upper Cambrian fossils were identical with those of Murchison's Lower Silurian; and the fact that the two systems of Cambrian and Silurian included beds on approximately the same horizon came to be realised in part by Murchison in 1842 and 1843, and more clearly by both Sedgwick and Murchison in 1846.




SIR RODERICK IMPEY MURCHISON.
From a photograph.

Eventually it was made manifest that the Llandeilo Beds were older than the Bala group, and that the Caradoc Beds (in part) of Murchison were equivalent to those of Bala. The main source of the trouble which arose and led to a painful controversy, had been in the confusion between the Caradoc Sandstone and the sandstones afterwards separated by Sedgwick in 1852 under the name of May Hill Sandstone (the Llandovery rocks of the Geological Survey). Thus, as remarked by Professor Hughes, "the Caradoc had to be defined, and some of the sandstones referred to it had to be included in the Bala Beds, and some to be bracketed with the overlying Silurian."

The establishment of this important point should have ended the controversy. Unfortunately it was not so, and Murchison, whose magnificent work on the *Silurian System* had been published in 1839,¹ was loth to modify his classification. Finding that his Llandeilo Beds did not form a true foundation, he "took into his Lower Silurian bed after bed of Sedgwick's Cambrian down to the base of the Lingula Flags."²

¹ It was actually issued towards the close of 1838, in two parts, with geological map, at the price of eight guineas.

² *Life and Letters of Sedgwick*, vol. ii., 1890, pp. 279, 543. See also Sedgwick and McCoy, *British Palæozoic Rocks and Fossils* (1855).



Older and Newer Systems Elucidated 133

This injustice was resented by many geologists, and in consequence for some years different systems of classification were adopted. The matter was practically set at rest in 1879 by Professor Lapworth, who introduced the term ORDOVICIAN for the Upper Cambrian of Sedgwick, and that portion of the Lower Silurian of Murchison which extends from the Bala and Caradoc Beds down to the base of the Arenig series.¹ Thus was constituted an independent system of great importance, which has been generally adopted.


The researches of JOACHIM BARRANDE (1799–1883), embodied in his great work *Système Silurien du Centre de la Bohême* (1852–1881), led him to recognise in the older rocks of that country three great faunas: the first, or Primordial Fauna, was practically equivalent to the Cambrian; the second Fauna to the Ordovician; and the third Fauna in great part to the Silurian. Following Murchison, he had unfortunately employed the term Silurian in the enlarged sense, but the results of his researches abundantly justified the classification of Professor Lapworth. During his life Barrande issued, mainly at his own expense, twenty-one quarto volumes dealing with the strata and their fossils; while two other volumes were published after his death.

¹ *Geol. Mag.*, 1879, p. 1.

Barrande included in his higher Silurian stages some strata that have since been placed with the Devonian by Professor E. Kayser. He also found certain characteristic groups of fossils of Upper Silurian type in some of his Lower Silurian strata, and regarded them as "colonies" which reappeared at higher horizons. This view was contested by geologists in Bohemia, and in 1880 by Dr. J. E. Marr, who attributed the features to the effects of dislocation. Dr. Marr at the same time pointed out the distinction between the supposed "colonies" and the migrations of species which may cause them to recur in beds of the same great group of strata, but not in distinct systems.

Although a few fossils have been found in rocks of Pre-Cambrian age, as elsewhere noted, it is not until we reach the base of the Cambrian that a clearly-defined fauna is met with.

The earliest fossiliferous stage in the Cambrian is characterised by the trilobite *Olenellus*, described by James Hall in 1862. Some fossils, now regarded as belonging to this zone, were discovered in 1844 in America by Ebenezer Emmons (1799-1863), who has been spoken of as the founder of American Palæozoic stratigraphy; but the organic remains were first fully described by C. D. WALCOTT in his monograph



on *The Fauna of the Lower Cambrian or Olenellus Zone*, issued in 1891.

Writing in 1888,¹ Professor Lapworth remarked that the *Olenellus* fauna had been also recognised in Scandinavia, while its presence in England had been first detected by him on the flanks of Caer Caradoc in 1885, but the specimens were too poor for description. He had since obtained examples of a large and well-marked species which he named *Olenellus Callavei*, after Dr. Charles Callaway.

Detailed researches on the Cambrian strata of South Wales, commenced by J. W. Salter and H. Hicks, led to the establishment, in 1865, of the Menevian group, which is characterised by the trilobite *Paradoxides*. The genus, which was described by Alexandre Brongniart in 1822, sometimes attains a length of more than two feet. Its horizon is above that of *Olenellus*. The uppermost Cambrian division is characterised by another trilobite, the *Olenus*.

The fact brought out by Mr. Walcott's researches that the *Olenellus* fauna comprises Spongida, Hydrozoa, Actinozoa, Echinodermata, Brachiopoda, Lamellibranchiata, Gastropoda, Pteropoda, Crustacea, and Trilobita, to say nothing of sundry trails and burrows

¹ *Nature*, Dec. 27, 1888, p. 212.

probably representing *Vermidea*, shows how varied was the life at that early period. As he remarked, the fossils "prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favourable conditions to discover it."

In the United States a great controversy, which extended over more than fifty years, arose over the name Taconic, which was given in 1842 by Emmons to a system which he regarded as older than the Potsdam Sandstone, described by him in 1838, and now grouped as Upper Cambrian. The name was taken from the Taconic Mountains on the borders of New York and Massachusetts, but the region, as subsequent observations have shown, is remarkably complicated; and Emmons included in his system strata that were afterwards shown to be in part Lower Silurian or Ordovician and in part Lower Cambrian.¹ Mr. G. P. Merrill (1906) has remarked that the term Taconic to-day "finds no place except historically in American geology."

In the complicated region of the Southern Uplands of Scotland order was established in the Lower Palæozoic strata in 1878 and subsequent years by Professor CHARLES LAPWORTH,

¹ See Chamberlin and Salisbury, *Geology*, ii., p. 245.

Older and Newer Systems Elucidated 137

who worked out in detail the numerous zones characterised especially by graptolites.

Through the work also of J. G. O. LINNARSSON (1841-1881) on the Lower Palæozoic formations of Sweden, as pointed out by Professor Lapworth, the sequence established among these older rocks and their organic remains had come to be regarded "as the most reliable and authoritative standard of reference yet defined." Angelin (1805-1876) had previously determined the successive forms of trilobites that characterise the Swedish strata; while Linnarsson dealt more particularly with the graptolites. In the course of his work he had to encounter many difficulties, partly from the fact that "In Southern Sweden the strata are of such remarkable tenuity that the fossils peculiar to several subformations in the vertical series lie in close proximity, and, unless collected inch by inch, *in situ*, are certain to become intermixed in the collection." In 1876 Linnarsson contributed a paper on the "Vertical Range of the Chief Types of Graptolites in Sweden," and it is specially interesting to know that the succession corresponded precisely with that determined by Professor Lapworth in Britain. Ultimately their separate labours "placed it absolutely beyond question that the grander Graptolitic zones recognisable among the Lower Palæozoic rocks of this country have

their exact parallels in Sweden, and are characterised by the same, or by a representative series of these fossils."¹

Another Swedish geologist, Gustaf Lindström (1829-1901), was distinguished for his work on the Silurian fossils of Gothland; and to him was owing the true interpretation of the peculiar coral *Calceola* from the Devonian, a form at one time regarded as an abnormal brachiopod.

The OLD RED SANDSTONE had been classed by Conybeare, Buckland, and Lyell as a lower and subordinate part of the Carboniferous strata; whereas they admitted that there was a marked separation in the south-west of England between the Carboniferous and the overlying New Red Sandstone.

In his *Silurian System*, of 1839, Murchison remarked that "Being convinced that the Old Red Sandstone is of greater magnitude than any of the overlying groups, I venture, for the first time in the annals of British geology, to apply to it the term system."

Two years later Hugh Miller (1802-1856), who had worked as a quarryman in the rocks near Cromarty, dedicated to Murchison his volume on *The Old Red Sandstone*, stating that but for the influence of that geologist the formation probably would have been degraded

¹ *Geol. Mag.*, 1882, pp. 1, etc.

Older and Newer Systems Elucidated 139

altogether from its place in the geological scale. It was not generally recognised abroad, the fact




LOUIS AGASSIZ.
From a photograph.

being that the equivalent strata were of different type—the type now known as Devonian

Remarkable forms of fishes were obtained from the Old Red Sandstone by Miller, and also by Robert Dick, baker, of Thurso; but many of these are now grouped in a distinct class, the Agnatha, among them being *Asterolepis*, *Bothriolepis*, *Cephalaspis*, *Pteraspis*, and *Pterichthys*. The true Fishes include *Coccosteus*, *Dipterus*, *Holoptychius*, and *Osteolepis*. Some of the forms were very large, the *Asterolepis* attaining a length of twenty feet.

Miller's *Old Red Sandstone* was regarded by Owen and others as "the most fascinating book ever written on a geological subject."

To AGASSIZ (1807-1873) we are indebted for the great work, *Recherches sur les Poissons Fossiles*, published during the years 1833-45; and he aided and encouraged Sir Philip Egerton (the tenth baronet, 1806-1881) to devote special attention to the subject. Agassiz in 1847 became Professor of Zoölogy and Geology at Harvard College (now the University), at Cambridge, Massachusetts, and his subsequent work was mainly zoölogical. One of his students, N. S. Shaler (1841-1906), who was afterwards a distinguished palæontologist and geologist, remarked of Agassiz in 1859 that "His face was the most genial and engaging that I had ever seen, and his manner captivated me altogether." Speaking to his students, "He said he should require of us in our several de-



partments first a monograph, second a scientific lecture, third a popular lecture, fourth a simple child's tale." It is interesting to learn that Shaler's *First Book of Geology*, published in 1884, was translated into German, Russian, and Polish, and also embossed in print-characters for the use of the blind.¹

In 1836 Sedgwick and Murchison commenced a detailed examination of the older strata of Devonshire, with the view, at first, of determining the age of the Culm-measures which had been included in the Greywacke group. Their field-observations enabled them to decide that the Culm-bearing strata were of Carboniferous age, and included representatives of the true Coal-measures. The subject, however, grew in interest, and they devoted attention during the three following years to the elucidation of the age and succession of the older strata. Aided by the local knowledge and collections of fossils made by Godwin-Austen and by S. R. Pattison, they determined the broad general sequence of the rocks. Sedgwick, indeed, in 1820 had noted that the fossils of the Plymouth limestone were distinct from those of the Mountain limestone; and William Lonsdale, in December, 1837, expressed his opinion, from an examination of the South Devon fossils collected by

¹ *Life of Shaler*, 1909, p. 427.

Godwin-Austen, that they belonged to a period between the Carboniferous and Silurian systems, and were, consequently, of the age of the Old Red Sandstone. This view was communicated to Sedgwick and Murchison, who in 1839 proposed that the name DEVONIAN be given to the great system of strata below the Carboniferous in the south-west of England. Thus the Cornish killas (in great part), the Plymouth and Torquay limestones, and other strata of slate and grit, came to be grouped as Devonian. Fish-remains of Old Red Sandstone type (*Cephalaspis*, *Pteraspis*, etc.) were subsequently found by C. W. Peach, Pengelly, and others, in the older Devonian rocks near Looe and Fowey.

Nevertheless, while the system, as a whole, was well founded, the precise palæontological relations of the Devonian and Carboniferous were not established, and no definite base to the Devonian was discovered. Subsequent research has shown how much more complex is the structure in Cornwall and South Devon, and even in North Devon and West Somerset, than was at first supposed.

The establishment of the Devonian system in England stimulated research on the equivalent strata on the Continent, and especially on the borders of France, Belgium, and Germany, in the Ardennes, and country eastward to the Eifel and Coblenz. To the geologists in those

areas we are mainly indebted for the determination of the sequence of the subdivisions and **their** fossils. F. A. Roemer in 1844 was one of **the** earlier workers who recognised the Devonian **rocks** in the Eifel district. To Dumont (1809–1857) we owe in 1848 the names Gedinian, Coblenzian, and Eifelian, but he failed to recognise that the strata were equivalent to the Old Red Sandstone, and ignored the name Devonian: perhaps because (as stated in an obituary notice) “it was his rule to form his judgment entirely upon his own observations.”

By the brothers G. and F. Sandberger a great advance was made in their work on the Devonian of Nassau (1850–56), where the main palæontological subdivisions were marked out in the Upper, Middle, and Lower Devonian. To Von Dechen in 1855, to G. Dewalque, Professor J. Gosselet, Professor E. Kayser, and others in subsequent years, our knowledge is largely due; and English geologists (notably Mr. W. A. E. Ussher) have availed themselves of the divisions made in Germany and other countries in Northern Europe to elucidate the sequence in the more highly disturbed parts of the south-west of England.

The term CARBONIFEROUS, adopted by Conybeare from the French, has been employed for the great series of Coal-bearing strata. The lower division, long known as Mountain lime-

Barrande included in his higher Silurian stages some strata that have since been placed with the Devonian by Professor E. Kayser. He also found certain characteristic groups of fossils of Upper Silurian type in some of his Lower Silurian strata, and regarded them as "colonies" which reappeared at higher horizons. This view was contested by geologists in Bohemia, and in 1880 by Dr. J. E. Marr, who attributed the features to the effects of dislocation. Dr. Marr at the same time pointed out the distinction between the supposed "colonies" and the migrations of species which may cause them to recur in beds of the same great group of strata, but not in distinct systems.

Although a few fossils have been found in rocks of Pre-Cambrian age, as elsewhere noted, it is not until we reach the base of the Cambrian that a clearly-defined fauna is met with.

The earliest fossiliferous stage in the Cambrian is characterised by the trilobite *Olenellus*, described by James Hall in 1862. Some fossils, now regarded as belonging to this zone, were discovered in 1844 in America by Ebenezer Emmons (1799-1863), who has been spoken of as the founder of American Palæozoic stratigraphy; but the organic remains were first fully described by C. D. WALCOTT in his monograph

on *The Fauna of the Lower Cambrian or Olenellus Zone*, issued in 1891.

Writing in 1888,¹ Professor Lapworth remarked that the *Olenellus* fauna had been also recognised in Scandinavia, while its presence in England had been first detected by him on the flanks of Caer Caradoc in 1885, but the specimens were too poor for description. He had since obtained examples of a large and well-marked species which he named *Olenellus Callavei*, after Dr. Charles Callaway.

Detailed researches on the Cambrian strata of South Wales, commenced by J. W. Salter and H. Hicks, led to the establishment, in 1865, of the Menevian group, which is characterised by the trilobite *Paradoxides*. The genus, which was described by Alexandre Brongniart in 1822, sometimes attains a length of more than two feet. Its horizon is above that of *Olenellus*. The uppermost Cambrian division is characterised by another trilobite, the *Olenus*.

The fact brought out by Mr. Walcott's researches that the *Olenellus* fauna comprises Spongida, Hydrozoa, Actinozoa, Echinodermata, Brachiopoda, Lamellibranchiata, Gastropoda, Pteropoda, Crustacea, and Trilobita, to say nothing of sundry trails and burrows

¹ *Nature*, Dec. 27, 1888, p. 212.

probably representing *Vermidea*, shows how varied was the life at that early period. As he remarked, the fossils "prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favourable conditions to discover it."

In the United States a great controversy, which extended over more than fifty years, arose over the name Taconic, which was given in 1842 by Emmons to a system which he regarded as older than the Potsdam Sandstone, described by him in 1838, and now grouped as Upper Cambrian. The name was taken from the Taconic Mountains on the borders of New York and Massachusetts, but the region, as subsequent observations have shown, is remarkably complicated; and Emmons included in his system strata that were afterwards shown to be in part Lower Silurian or Ordovician and in part Lower Cambrian.¹ Mr. G. P. Merrill (1906) has remarked that the term Taconic to-day "finds no place except historically in American geology."

In the complicated region of the Southern Uplands of Scotland order was established in the Lower Palæozoic strata in 1878 and subsequent years by Professor CHARLES LAPWORTH,

¹ See Chamberlin and Salisbury, *Geology*, ii., p. 245.

who worked out in detail the numerous zones characterised especially by graptolites.

Through the work also of J. G. O. LINNARSSON (1841-1881) on the Lower Palæozoic formations of Sweden, as pointed out by Professor Lapworth, the sequence established among these older rocks and their organic remains had come to be regarded "as the most reliable and authoritative standard of reference yet defined." Angelin (1805-1876) had previously determined the successive forms of trilobites that characterise the Swedish strata; while Linnarsson dealt more particularly with the graptolites. In the course of his work he had to encounter many difficulties, partly from the fact that "In Southern Sweden the strata are of such remarkable tenuity that the fossils peculiar to several subformations in the vertical series lie in close proximity, and, unless collected inch by inch, *in situ*, are certain to become intermixed in the collection." In 1876 Linnarsson contributed a paper on the "Vertical Range of the Chief Types of Graptolites in Sweden," and it is specially interesting to know that the succession corresponded precisely with that determined by Professor Lapworth in Britain. Ultimately their separate labours "placed it absolutely beyond question that the grander Graptolitic zones recognisable among the Lower Palæozoic rocks of this country have

their exact parallels in Sweden, and are characterised by the same, or by a representative series of these fossils."¹

Another Swedish geologist, Gustaf Lindström (1829-1901), was distinguished for his work on the Silurian fossils of Gothland; and to him was owing the true interpretation of the peculiar coral *Calceola* from the Devonian, a form at one time regarded as an abnormal brachiopod.

The OLD RED SANDSTONE had been classed by Conybeare, Buckland, and Lyell as a lower and subordinate part of the Carboniferous strata; whereas they admitted that there was a marked separation in the south-west of England between the Carboniferous and the overlying New Red Sandstone.

In his *Silurian System*, of 1839, Murchison remarked that "Being convinced that the Old Red Sandstone is of greater magnitude than any of the overlying groups, I venture, for the first time in the annals of British geology, to apply to it the term system."

Two years later Hugh Miller (1802-1856), who had worked as a quarryman in the rocks near Cromarty, dedicated to Murchison his volume on *The Old Red Sandstone*, stating that but for the influence of that geologist the formation probably would have been degraded

¹ *Geol. Mag.*, 1882, pp. 1, etc.

altogether from its place in the geological scale. It was not generally recognised abroad, the fact



LOUIS AGASSIZ.
From a photograph.

being that the equivalent strata were of different type—the type now known as Devonian.

Remarkable forms of fishes were obtained from the Old Red Sandstone by Miller, and also by Robert Dick, baker, of Thurso; but many of these are now grouped in a distinct class, the Agnatha, among them being *Asterolepis*, *Bothriolepis*, *Cephalaspis*, *Pteraspis*, and *Pterichthys*. The true Fishes include *Coccosteus*, *Dipterus*, *Holoptychius*, and *Osteolepis*. Some of the forms were very large, the *Asterolepis* attaining a length of twenty feet.

Miller's *Old Red Sandstone* was regarded by Owen and others as "the most fascinating book ever written on a geological subject."

To AGASSIZ (1807-1873) we are indebted for the great work, *Recherches sur les Poissons Fossiles*, published during the years 1833-45; and he aided and encouraged Sir Philip Egerton (the tenth baronet, 1806-1881) to devote special attention to the subject. Agassiz in 1847 became Professor of Zoölogy and Geology at Harvard College (now the University), at Cambridge, Massachusetts, and his subsequent work was mainly zoölogical. One of his students, N. S. Shaler (1841-1906), who was afterwards a distinguished palæontologist and geologist, remarked of Agassiz in 1859 that "His face was the most genial and engaging that I had ever seen, and his manner captivated me altogether." Speaking to his students, "He said he should require of us in our several de-

Older and Newer Systems Elucidated 141

partments first a monograph, second a scientific lecture, third a popular lecture, fourth a simple child's tale." It is interesting to learn that Shaler's *First Book of Geology*, published in 1884, was translated into German, Russian, and Polish, and also embossed in print-characters for the use of the blind.¹

In 1836 Sedgwick and Murchison commenced a detailed examination of the older strata of Devonshire, with the view, at first, of determining the age of the Culm-measures which had been included in the Greywacke group. Their field-observations enabled them to decide that the Culm-bearing strata were of Carboniferous age, and included representatives of the true Coal-measures. The subject, however, grew in interest, and they devoted attention during the three following years to the elucidation of the age and succession of the older strata. Aided by the local knowledge and collections of fossils made by Godwin-Austen and by S. R. Pattison, they determined the broad general sequence of the rocks. Sedgwick, indeed, in 1820 had noted that the fossils of the Plymouth limestone were distinct from those of the Mountain limestone; and William Lonsdale, in December, 1837, expressed his opinion, from an examination of the South Devon fossils collected by

¹ *Life of Shaler*, 1909, p. 427.

Godwin-Austen, that they belonged to a period between the Carboniferous and Silurian systems, and were, consequently, of the age of the Old Red Sandstone. This view was communicated to Sedgwick and Murchison, who in 1839 proposed that the name DEVONIAN be given to the great system of strata below the Carboniferous in the south-west of England. Thus the Cornish killas (in great part), the Plymouth and Torquay limestones, and other strata of slate and grit, came to be grouped as Devonian. Fish-remains of Old Red Sandstone type (*Cephalaspis*, *Pteraspis*, etc.) were subsequently found by C. W. Peach, Pengelly, and others, in the older Devonian rocks near Looe and Fowey.

Nevertheless, while the system, as a whole, was well founded, the precise palæontological relations of the Devonian and Carboniferous were not established, and no definite base to the Devonian was discovered. Subsequent research has shown how much more complex is the structure in Cornwall and South Devon, and even in North Devon and West Somerset, than was at first supposed.

The establishment of the Devonian system in England stimulated research on the equivalent strata on the Continent, and especially on the borders of France, Belgium, and Germany, in the Ardennes, and country eastward to the Eifel and Coblenz. To the geologists in those

areas we are mainly indebted for the determination of the sequence of the subdivisions and their fossils. F. A. Roemer in 1844 was one of the earlier workers who recognised the Devonian rocks in the Eifel district. To Dumont (1809-1857) we owe in 1848 the names Gedinnian, Coblenzian, and Eifelian, but he failed to recognise that the strata were equivalent to the Old Red Sandstone, and ignored the name Devonian: perhaps because (as stated in an obituary notice) "it was his rule to form his judgment entirely upon his own observations."

By the brothers G. and F. Sandberger a great advance was made in their work on the Devonian of Nassau (1850-56), where the main palæontological subdivisions were marked out in the Upper, Middle, and Lower Devonian. To Von Dechen in 1855, to G. Dewalque, Professor J. Gosselet, Professor E. Kayser, and others in subsequent years, our knowledge is largely due; and English geologists (notably Mr. W. A. E. Ussher) have availed themselves of the divisions made in Germany and other countries in Northern Europe to elucidate the sequence in the more highly disturbed parts of the south-west of England.

The term CARBONIFEROUS, adopted by Conybeare from the French, has been employed for the great series of Coal-bearing strata. The lower division, long known as Mountain lime-

stone, came to be grouped as Carboniferous because it was found to contain productive coal-seams in the north of England and Scotland.

For a special study of the fossils of the Carboniferous rocks of Belgium we are indebted to LAURENT GUILLAUME DE KONINCK (1809-1887), and it is a noteworthy fact that from 1835 until the close of his life he was occupied as a Professor of Chemistry. As early as 1838 he commenced to publish the results of his researches on palæontology; during the years 1842-51 he issued his first great work on the Carboniferous fossils; and in 1876 he was appointed Professor of Palæontology in the University of Liège. The subsequent labours of geologists in Belgium and elsewhere have added largely to our knowledge of the succession of the organic remains. Indeed, of late years especial attention has been given to the Carboniferous zones as indicated by the plants, corals, brachiopods, mollusca, fishes, and other organisms.

The name PERMIAN was suggested in 1841 by Murchison from the ancient Kingdom of Permian in Russia, for strata equivalent to the Lower New Red Sandstone or Magnesian Limestone series of Britain; and to the Rothliegende and Zechstein (with Kupferschiefer) of Germany and other parts of Europe.

Thus the term New Red Sandstone, which was applied to the strata newer than the Carbonifer-

ous in distinction from the Old Red Sandstone at the base of that system, came to be subdivided, the Lower New Red Sandstone being linked with the Palæozoic, the Upper with the Mesozoic. This last name was introduced by John Phillips. Murchison observed (and Sedgwick had also) that "there are exceptional tracts in which the Carboniferous and overlying Permian deposits are in apparently conformable relation to each other"; but elsewhere there was evidence of great discordance. He found near Perm the characteristic fossils of the Zechstein, and remarked that "Subordinate, however, as it is in some tracts of Russia, the Zechstein is so magnificently displayed in others, in masses of both limestone and gypsum, that it more than rivals the finest sections of that deposit, whether to the south of the Harz or in Thuringia."¹

The Magnesian Limestone series was investigated in detail by Sedgwick during the years 1821-23, and in a paper published in 1829 he was the first to correlate the subdivisions of the entire New Red Sandstone series of Germany with the strata in Britain.

The term TRIAS, introduced in 1834 by Friederich von Alberti (1795-1878), was intended to indicate the threefold division of the

¹ *Siluria*, ed. 5 (1872), pp. 308, 309, 311.

German strata into Bunter, Muschelkalk, and Keuper. This name has been universally adopted, although the subdivisions on which it is based can be considered only as local. Thus the Muschelkalk is not represented in its fossiliferous facies in Britain. Other local divisions are recognised in the Alpine Trias, while E. von Mojsisovics, in dealing with the physical history and palæontology of the system, especially in Southern Europe, has grouped the strata under five main subdivisions and fourteen zones.

The highest stage of the Trias, the Rhætic Beds (or zone of *Avicula contorta*), were so named by Dr. C. W. Gümbel from the Rhætian Alps of the Grisons in south-eastern Switzerland on the borders of Lombardy. In Northern Italy we are indebted especially to Stoppani (1824-91) for researches on the Rhætic and overlying Liassic strata.

In 1836 Dr. James Deane called attention to some flagstones from the "New Red Sandstone" of the Connecticut Valley that were placed as a door-step in front of a house, and contained impressions of fossil footprints. These impressions were regarded by the Rev. Edward Hitchcock as tracks of birds, and he applied the name *Ornithichnites* in the same year. Other footprints and tracks were from time to time found, and some were referred in 1848 by

Hitchcock to batrachians, chelonians, lizards, and annelids or molluscs. Lyell thought that most of the footprints might be referred to birds, and, although some were of great size, he instanced the *Dinornis* as capable of having produced markings quite as large. In 1858 Hitchcock published a large work on the *Ichnology of New England*. His views were contested in 1860 by Mr. R. Field, on whose property the first slabs were discovered; and this observer expressed his conviction that all the tracks were reptilian. In 1893 reptilian bones were found in the strata; they were referred by O. C. Marsh to a dinosaur (*Anchisaurus colurus*), and he pointed out that the markings might all have been caused by such an animal, under different conditions, mainly by the hind feet, in part by the tail and fore feet.¹


The importance of fossils in fixing the age of formations, where the test of stratigraphical sequence is not clear, was shown in the case of the red sandstones near Elgin. Agassiz in 1844 described, under the name *Stagonolepis*, some vertebrate scutes from the "Old Red Sandstone" of Lossiemouth, believing the remains to belong to a fish. Huxley, however, determined in 1858 that the genus was Crocodilian. Meanwhile, Mantell in 1852 described

¹ See Merrill (1906), p. 625.

remains of *Telerpeton*, while Huxley in 1859 obtained remains of another reptile, *Hyperodapedon*, from the same set of strata—the remains being all Triassic forms. Thus a long-disputed question was settled, and it was proved that true Old Red Sandstone with *Holoptychius* occurred in the district, together with overlying beds of Triassic red sandstone, in which the reptilian remains were preserved.

In the JURASSIC system, to which reference has been previously made, the order of sequence in the strata has been established in many European countries on the basis of the original grouping of William Smith. The labours of F. A. VON QUENSTEDT (1809–1889) on the zonal sequence of the Jurassic fossils have formed the basis of much of the work done by subsequent geologists. Distinguished also for researches on mineralogy and crystallography, he commenced the publication of his palæontological work in 1843, and issued his *Der Jura* in two volumes in 1858, and a work on Jurassic Ammonites in 1888. Moreover, the able work of ALBERT OPPEL (1831–1865), *Die Juraformation Englands, Frankreichs und des Südwestlichen Deutschlands* (1856–58), aroused keen interest, and largely aided the researches carried on by many local workers.

The term CRETACEOUS was adopted by FITTON from the French for the system char-



acterised over extensive areas by the Chalk formation.

In England the Wealden and Purbeck Beds, the latter usually grouped with the Jurassic, are intimately associated in method of formation as one great fresh-water and estuarine series. Nevertheless, both in Europe and America the Lower Cretaceous plants, fishes, and reptiles have been regarded by some authorities as having Jurassic rather than Cretaceous affinities.

To Mantell and Fitton we are primarily indebted for our knowledge of the English Cretaceous strata; to the brothers F. A. Roemer (1809-1869) and C. F. von Roemer (1818-1891), and to C. F. H. Credner (1809-1876), for researches on the Jurassic and Cretaceous rocks of Germany; and to H. B. Geinitz for observations on the Quadersandstein, representative of part of the Upper Chalk of other areas, and well seen in the sandstone cliffs of Saxon Switzerland.

To EDMOND HÉBERT (1812-1890), Professor of Geology at the Sorbonne in Paris, and one of the leading geologists of France, we owe the determination of the main zones in the Upper Cretaceous strata. His work was extended by Dr. Charles Barrois, and further amplified by the later researches of Mr. A. J. Jukes-Browne and Dr. A. W. Rowe.

The term Cainozoic was introduced by John

Phillips as a synonym for the Tertiary era; but since the separation of the Quaternary by A. Morlot in 1854, the Cainozoic may be taken to include the two eras.

The method of identifying the EOCENE, MIOCENE, and PLIOCENE systems by means of the percentage of the genera and species of mollusca now living, as introduced by Lyell and Deshayes in 1829, was challenged by Mr. W. H. Dall in 1903, because conditions for the survival of species may be more favourable in one region than in another. Only two or three species appear to be identical in the Eocene of America and Europe.

The classification of the Tertiary strata of Belgium is largely due to the researches of Dumont in 1839 and subsequent years, and some of his names have been adopted in general schemes of nomenclature.

To Prestwich we owe the main subdivisions in the Eocene strata of England, and the determination of the physical conditions under which the strata were accumulated.

The term OLIGOCENE was introduced in 1854 by H. E. Beyrich (1815-1896), an authority on the mollusca of the Tertiary period, and distinguished for his wide knowledge of the rocks and fossils of various formations in Germany and Central Europe.

Edward Forbes elucidated the geological

history of the Fluvio-marine series, now known as Oligocene, in the Isle of Wight; and quite recently Mr. and Mrs. Clement Reid have concluded from the evidence of the plants that the Lignite series of Bovey Tracey, in Devon (referred by Heer to the Miocene, and by J. Starkie Gardner to the Eocene), represents the highest portion of the Oligocene.

The term Neogene was introduced in 1864 for the Miocene and Pliocene by M. Hoernes (1815-1868), well known for his researches on the Tertiary mollusca of the Vienna basin.

The Pliocene beds of East Anglia and those of Belgium have attracted much attention on account of the abundance of mollusca and other fossils. As remarked (p. 48), some Eocene genera are similar to those of the Crag, and casts of mollusca found at Lenham, in Kent, were at one time referred to the older Tertiary strata; but subsequent evidence clearly showed that the fossils were of the age of the older Pliocene or Diestian of Belgium.

The term **PLEISTOCENE** was applied by Lyell in 1839 to deposits newer than the Pliocene, and these are now grouped, together with the later Recent or Holocene accumulations, in the Quaternary era.

The Superficial or Drift deposits, referred to by old writers as "Extraneous Rubbish," and by some divided into Diluvium and Alluvium,

came to be understood when Agassiz and Buckland pointed out the former extent of glacial action in the northern hemisphere. To Agassiz, indeed, we are indebted for the first clear demonstration of the great glaciation that took place in Post-Pliocene or Pleistocene times.

The grooves and striæ on the surfaces of rocks and boulders, the transport of great blocks of rock and stones a long distance—sometimes hundreds of miles—from their parent source, and across valleys that had been subsequently deepened, were noted by some of the earlier students of geology—by Sir James Hall, of Dunglass, by De Luc, Brongniart, Conybeare, Lyell, Murchison, Bigsby, Joshua Trimmer, and others.

It was not, however, until November, 1840, that Agassiz, then of Neuchâtel, read before the Geological Society of London a paper "On Glaciers, and the Evidence of their having once existed in Scotland, Ireland, and England."¹ Three years previously the author had studied the Alpine regions and the polished and striated surfaces of the rocks which form the beds of glaciers. Many others had investigated the subject, and indicated the former local extent of the glaciers.

¹ *Proc. Geol. Soc.*, iii., p. 327.

The problem which Agassiz now faced was the extent of erratic boulders "over all the temperate and northern regions of Europe, Asia, and America"; and he had "arrived at the conviction that the formation of glaciers did not depend upon the actual configuration of the globe, but was also connected with the last great geological changes in its surface, and with the extinction of the great mammals which are now found in the polar ice."¹ In the autumn of 1840 he came to Great Britain and saw the evidence of moraines in various parts of the north of England, in Scotland, and Ireland; likewise the striated and polished surfaces of the rocks, and the rounded bosses or *roches moutonnées*. If the analogy of the facts with those in Switzerland be correct, then, as Agassiz remarked, it must be admitted "that not only glaciers once existed in the British Islands, but that large sheets (*nappes*) of ice covered all the surface." These great sheets resembled those existing in Greenland, and the "unstratified gravel," now spoken of as Boulder drift or Boulder clay, "was in general produced by the trituration of the sheets of ice upon the subjacent surface." He referred also to the moraines left on the retreat of the glaciers, and to the "enormous debacles" resulting from the

¹ See p. 30.

disappearance of great bodies of ice. In the evidence of these phenomena Buckland was disposed to recognise his great Flood.¹ Agassiz further instanced the famous parallel roads of Glen Roy as due to a lake produced by the extension of a lateral glacier, observing that "Lakes thus formed naturally gave rise to stratified deposits and parallel roads, or beds of detritus at different levels."

Since the days of William Smith no more momentous, and, as time has proved, no sounder, explanation of a vast and difficult problem had been given in geological science. Years elapsed, however, before the theory of the great influence of land-ice during the Glacial period was generally accepted. Floating ice and coast-ice were held by many to have been prime causes of the formation and dispersal of Boulder clay. The publication of Sir Archibald Geikie's essay on *The Phenomena of the Glacial Drift of Scotland*, in 1863, and of Professor James Geikie's volume on *The Great Ice Age*, in 1874, paved the way for the more general acceptance of land-ice as the chief agent in the formation of Boulder clay or till.

The importance of studying and mapping in detail the superficial deposits was urged by Trimmer, who discerned their bearing on

¹ See Sollas (1905), p.24

Older and Newer Systems Elucidated 155

soils and made proposals in 1850 for a geological survey specially directed to agricultural objects.

At a later date Searles V. Wood, Jr., commenced the systematic mapping of the Drift Deposits in East Anglia, and did much to interpret the history of these complex, but highly interesting, accumulations.

The actual mapping of soils has not been practicable, but the notation suggested by Trimmer to indicate their character and depth has been adopted in a form suitable for local purposes on soil-maps published in Germany and in the United States.

CHAPTER VII

PALÆONTOLOGY AND THE SUCCESSION OF LIFE

THE term Palæontology, which is taken to include the study of fossil plants and animals, was introduced by Fischer de Waldheim in his *Bibliographia Palæontologica*, published at Moscow in 1834; and the name appears to have been used at about the same date by de Blainville.¹

Among the more distinguished palæontologists of the middle of the nineteenth century, France claims ALCIDE D'ORBIGNY (1802-1857), who in 1840 commenced the publication of his great work *Paléontologie Française*. In the first six volumes he described and figured the mollusca, brachiopoda, bryozoa, and echinoidea of the Cretaceous strata, and in two later volumes he dealt with the cephalopoda and a number of the gasteropoda of Jurassic age. In 1853 he became

¹ See Zittel (1901), p. 363. Gotthelf Fischer (1771-1853) was born at Waldheim in Saxony, and in 1804 became Professor of Natural History in the University of Moscow.



ALCIDE D'ORBIGNY.
From a lithographic portrait.

Professor of Palæontology in the Museum of Natural History at Paris, a post specially created for him, and, although he did not live to complete his descriptions of the Cretaceous and Jurassic fossils,¹ yet on these and other subjects d'Orbigny left a grand and lasting monument of enthusiastic labour.

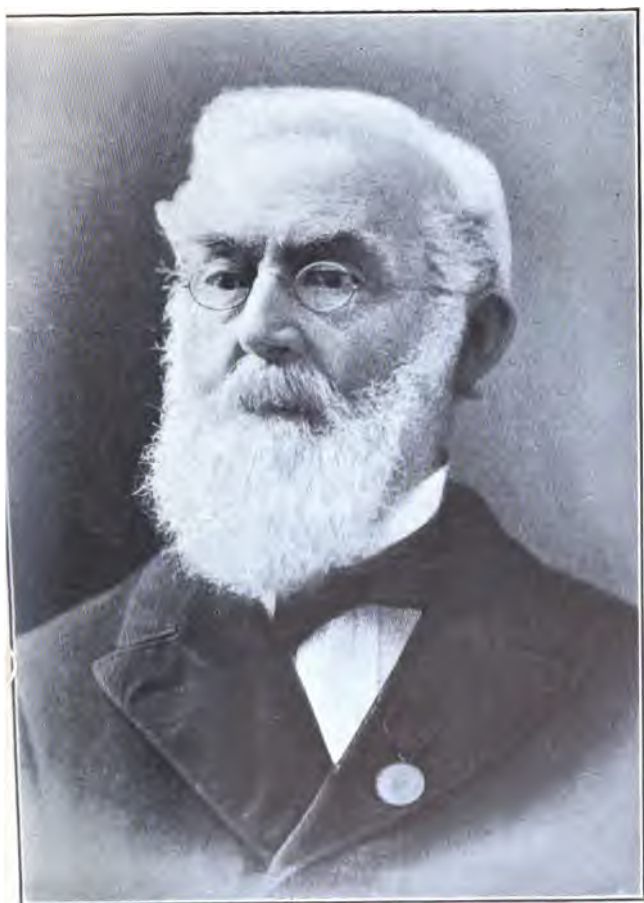
The Vicomte D'ARCHIAC (1802-1868), after serving nine years as a cavalry officer in France, devoted his attention to fossils and their distribution in various geological formations, and in 1864-65 issued his *Paléontologie Stratigraphique*. In Switzerland the famous *Traité de Paléontologie*, by F. J. PICTET, was first published in 1844-46. In Germany the *Lethæa Geognostica* of H. G. BRONN (1800-1862), an elaborate work published during the years 1834-37, became "one of the foundations of German stratigraphical geology," and placed the author "in the foremost rank of European palæontologists."²

OWEN (1804-1892), who was especially distinguished in geology for his researches on fossil reptiles, birds, and mammals, was author of the first general work issued in Britain under the title *Palæontology*, 1860.

The latest great work, that of K. A. VON

¹ The work was continued by other palæontologists. See record of the dates of publication by C. D. Sherborn, *Geol. Mag.*, 1899, p. 233.

² Address Geol. Soc., London, by A. C. Ramsay, 1863.




JAMES HALL.
From a photograph, 1891.

ZITTEL (1839-1904), Professor of Geology and Palæontology at Munich, was the *Handbuch der Paläontologie*, commenced in 1876, and completed in four volumes, after "seventeen years of strenuous labour," in 1893. This work, as remarked in 1904, "remains the most comprehensive and trustworthy treatise of reference on the subject with which it deals";¹ and it is to be remembered to his credit that Zittel was opposed to the excessive multiplication of names introduced by certain modern specialists.

In the United States JAMES HALL (1811-1898) had joined the New York Geological Survey in 1836, and seven years later became State Geologist and Director of the Museum of Natural History at Albany. His connection with the Survey extended over sixty-two years, but he was especially distinguished for his researches on the palæozoic invertebrata of New York. The chief results of his labours were published in thirteen large quarto volumes, in which he dealt with graptolites, trilobites, brachiopoda, mollusca, echinoidea, and crinoidea.

The progress of geology at home and abroad was likewise helped by works on local geology, in which the strata and their organic remains were described. Thus John Phillips (1800-

¹ Obit. by F. L. Kitchin, *Geol. Mag.*, 1904, p. 93.



Palæontology. Succession of Life 161

1874) prepared and issued in two volumes (1829 and 1836) *Illustrations of the Geology of Yorkshire*.

Distinguished as the first lady geologist who devoted her time and talents to the systematic study of the science, ETHELDRED BENETT (1776–1845) deserves mention as authoress of *A Catalogue of the Organic Remains of the County of Wilts*, published in Sir Richard Colt Hoare's *County History*, and reprinted for private circulation at Warminster in 1831. The daughter of Thomas Benett, Squire of Pyt House, near Tisbury, she investigated for many years the strata and fossils of the Vale of Wardour, and afterwards, during a residence at Warminster, made a fine collection of the fossils of the Upper Greensand, including many now famous sponges, of which the species known as *Hallirhoa agariciformis* and others were named by Miss Benett.¹ The silhouette reproduced on page 162 is from a copy presented to Samuel Woodward, who issued, in 1833, *An Outline of the Geology of Norfolk*.

In Britain the Palæontographical Society was instituted in 1847,² the object being "to figure and describe as completely as possible a stratigraphical series of British fossils." The first

¹ See G. J. Hinde, *Catalogue of Fossil Sponges* (Brit. Mus.), 1883.

² See record of foundation in *Geol. Mag.*, 1896, p. 385.

volume issued was that by S. V. Wood, *A Monograph of the Crag Mollusca*, Part I., Univalves, 1848.

Investigations in various parts of the world naturally brought about comparisons and cor-

relations of the larger divisions of the strata.

It was admitted that the geological formations of different districts and countries represented for the most part only certain conditions of the seabed of the period, and that, as pointed out by Sedgwick in 1831, changes in mineral character would be accompanied by corresponding changes in the forms of life characteristic of particular depths of water and other sedimentary con-



ETHELDRED BENETT.
From a silhouette, 1837.

ditions. Some forms of life, however, were shown to have a wide range, and to be comparatively independent of the sedimentary conditions.

Palæontology thus rightly came to rule in the

matter of chronology, certain fossils and groups of fossils being the recognised "time-keepers." Their testimony, however, requires to be regulated by the nature of the organisms, their capacity for migration, and the time likely to be occupied in dispersion.

The necessity, however, arose for a dual classification or nomenclature (1) for geological formations which represent particular conditions more or less local, and mark physical changes; and (2) for biological periods or epochs of varied duration, marked by organic changes, but not necessarily indicated, and then only locally, by prominent changes in the strata.

Alcide d'Orbigny¹ introduced in 1852,² and in part earlier, a nomenclature that should indicate successive periods in the history of geology. It was based on terms largely in use. Uniformity in termination was adopted as far as possible, so that the Oxford Clay became Oxfordian, the Great Oolite series of Bath the Bathonian, the Inferior Oolite of Bayeux the Bajocian, and so on. It was justly intended that well-known and long-established local formations and their fossils should be taken as the basis of the time-divisions; that, for example, the

¹ See p. 156.

² *Cours Élémentaire de Paléontologie et de Géologie Stratigraphiques*, vol. ii., 1852.

Kimeridge Clay fauna of Kimeridge, in Dorset, should be the guide to the Kimeridgian epoch.

Many Tables of Strata have been published since the days of William Smith, the most important being that of EUGÈNE RENEVIER (1831-1906), Professor of Geology and Palæontology at Lausanne. Nevertheless, it may be freely admitted that any attempt to tabulate the formations, and the epochs represented by them, for the world at large, is no more simple than would be the attempt to arrange the historic periods during which various rulers have governed states and countries. Precision is impossible, nor could it be expected.

As the formations came to be studied in detail, and over wide areas, so a definite sequence in the organic remains was manifest: certain forms, at any rate, being confined to particular stages. Thus the different formations, as previously noted, came to be divided, wherever possible, into a series of palæontological zones—the zones comprising an assemblage of fossils characterised by one dominant and widespread form, the name of which is used to designate the zone. Among the fossils taken as indices of zones the most serviceable are graptolites, trilobites, and ammonites; other forms, such as belemnites, brachiopods, echinoids, and corals, have been used more locally, as well as plants

and different vertebrata. Hence, as Dr. J. E. Marr has pointed out,¹ we now require a triple grouping in our Tables of Strata, so as to include the names of the palæontological zones that have been determined in different countries. Locally, zones may be definitely traced from place to place by the combined evidence of fossils and stratigraphy. When correlation is considered in countries far apart, as in Western Europe and India, in America and Australia, we must be content with general synchronism, based on the occurrence of widespread marine forms or of allied and representative species. Even among the Devonian rocks of the United States, as Professor H. Shaler Williams has shown in an important philosophical essay (1903), there is evidence of the shifting recurrence, and modification of faunas, opposed to the rigid artificial limits that are too often assigned to zones.

That there have been certain characteristic types of mineral characters in the formations of the great geological systems over extended areas, has been matter of comment from an early date in the nineteenth century; and Professor J. W. Gregory has lately referred to these "indications that the main earth-changes have been due to world-wide causes, which led

¹ Address to Geol. Soc., London, 1905.

to the predominance of the same types of sedimentary rocks during the same period in many regions of the world." He was, indeed, led to infer that "the landmarks of physical geology will probably be found to give more precise evidence as to geological synchronism than those of palæontology."¹

In 1909 Professor T. C. Chamberlin wrote on "Diastrophism as the Ultimate Basis of Correlation."² Diastrophism is a term that applies to all movements of the earth's crust, and the development of stratigraphy and palæontology is dependent on the grander earth-movements, which are indicated by unconformities and erosion, by terrestrial and fresh-water deposits, by the overlap of successive marine deposits, and other phenomena.

Turning now to the records of the existence of life on the earth, we find no positive evidence among the earlier Archæan rocks.

The supposed organism from the Laurentian rocks of Canada, named *Eozoon Canadense* in 1864 by J. W. Dawson (1820-1889), and regarded as showing a structure characteristic of Foraminifera, was for a long time a subject of controversy. Its organic nature is now finally rejected; the specimens forming instances of the

¹ Address to Geol. Section, Brit. Assoc. for 1907, p. 496.

² *Journ. Geol.* (Chicago), xvii., p. 685; see also Willis and Salisbury (1910).

“simulation of structures” of which other examples have been discussed by Dr. J. E. Marr.¹

It has, however, been considered possible that the carbonaceous material such as graphite, as well as cherts and limestones, may indicate the existence of life during the era when the oldest known rocks were formed.²

In the later Archæan or Pre-Cambrian rocks (termed Eozoic and Proterozoic) undoubted evidences of fossils have been obtained. Thus in 1899 Mr. C. D. Walcott recorded from the rocks in Montana, and in the Grand Canyon of the Colorado in Arizona, remains that may have belonged to eurypterids, brachiopods, and pteropods, as well as annelids. In Britain tracks and burrows attributed to worms have been observed in the Torridon Sandstone.

The Dawn of Life (as noted p. 136) evidently must have been far back in Pre-Cambrian time; but it may be doubted whether many definite remains can have been preserved. Theoretically, there is every justification in concluding, with Lamarck, that the lowlier types of life preceded the higher forms; and we know that many of the former have survived through long ages with comparatively little modification, so that the diversity among animals and plants is greater now than ever.

¹ *Stratigraphical Geology*, 1898, p. 72.


² *Chamberlin and Salisbury* (1906), pp. 159, 210, 216.

Much has been written on the imperfection of the geological record by Darwin, Huxley, Neumayr,¹ and others. It is natural that, of the organisms inhabiting water, more fossil than recent species are known; but there is a preponderance of other existing forms, largely owing to the number of insects, which are rarely preserved in the fossil state. Curiously enough, the oldest known insect appears to have been a bug named *Protocimex*, from the Ordovician of Sweden. Cockroaches may date from Silurian times, and many forms have been found, appropriately enough, in the Coal-measures. Dragonflies also occurred in the Carboniferous period.

As an indication of the rarity of preservation of some fossils it may be mentioned that the *Ceratodus*, a genus of fishes found in the Rhætic Beds in Gloucestershire, is known elsewhere in England only in the Stonesfield Slate of Oxfordshire, and is now living in the rivers of Queensland. As noted by Dr. A. Smith Woodward, it does not appear to have been preserved in strata higher than the Jurassic of Europe, North America, and Australia, but occurs in the Cretaceous of Patagonia and North Africa.

Among Coelenterata interesting discoveries were made in 1898, by Mr. C. D. Walcott, of imprints of medusæ or jelly-fishes in the Middle

¹ *Geol. Mag.*, 1889 p. 281.



Cambrian Shales of Alabama. The original form appears to have been preserved as a mould in certain siliceous nodules known as "star-cobbles."

Among the forms allied to Belemnites, *Belemnoteuthis* from the Oxfordian and *Geoteuthis* from the Lias have been preserved with their ink-bags. In 1826 Buckland obtained a specimen of the latter from Lyme Regis, and had a drawing made with the fossil ink or sepia, which was pronounced to be excellent. The facts show how accidentally, as it were, certain species have been preserved and discovered. So many agencies of decay occur whereby forms are destroyed, whether on land or in water, or subsequently by dissolution in the strata as well as by metamorphism of the rocks, that the remains preserved must always bear a small proportion to the number of forms which at one time or another existed.

The geological record shows that, while the Invertebrata preceded the Vertebrata, the appearance of the Vertebrata was in the order of their rank, commencing with the Agnatha, which are the earliest "fish-like animals."¹

¹ See *Guide to the Fossil Reptiles*, etc., Brit. Mus., by Dr. A. Smith Woodward, 1905, p. 53; "Some Ideas on Life," Pres. Address, 1903, by Dr. H. Woodward, *Journ. R. Micros. Soc.*, xxiii., p. 142; "The Evolution of Vertebrate Animals in Time," Pres. Address, 1904; *ibid.*, xxiv., p. 137.


Nevertheless, as Dr. A. Smith Woodward has remarked, "No links have yet been found between fishes and the invertebrate animals below." The earliest remains of Agnatha have been recorded by Mr. C. R. Eastman from the Ordovician of the United States; the earliest true fishes occur in the Silurian. Succeeding the Agnatha and Fishes, the Amphibia, Reptiles, Birds, and Mammalia came into existence, and finally Man.

Remains of Amphibia were discovered in the Coal-measures of Nova Scotia in 1852 by J. W. Dawson, the small genus *Dendrerpeton* having been found in a hollow of the trunk of a *Sigillaria*.

The Old Red Sandstone or Devonian has been regarded as the "Age of Fishes," the New Red Sandstone series as the "Age of Amphibians," the entire Secondary era as the "Age of Reptiles," the Tertiary as the "Age of Mammals and Birds," and the Quaternary as the "Age of Man."

The study of fossil plants was followed in early years by Adolphe Brongniart in France, by Count Sternberg in Germany, and by John Lindley and William Hutton in Britain.

The earliest known forms belong to the Algæ, but in strata of all ages there are often found plant-like forms or "fucoidal markings" that cannot be definitely identified. Some



Palæontology. Succession of Life 171

fossils originally described as *Eophyton* have since been referred to the trailings of animals.

Ehrenberg (1795-1876) was one of the earliest investigators of the micro-organisms of various geological formations. In his *Mikrogeologie*, 1854, the results of his principal investigations were published, but in 1838 he had described sundry "infusorial earths." These are now known to comprise deposits of Foraminifera, etc., as well as of Diatomaceæ, which belong to the Algæ. The last-named form the well-known recent deposits of Diatomite.

Some remains of Acrogens (Lycopods) have been recorded from Ordovician and Silurian strata; but, according to Professor A. C. Seward, the form named *Nematophycus*, referred to the Algæ, "constitutes the most satisfactory example of a Silurian plant."¹

The Devonian and Lower Carboniferous formations contain remains of aquatic and terrestrial plants, such as lycopods and horse-tails, probably the oldest known ferns, and some forms which combine the characters of ferns and cycads; they have yielded also *Cordaite*s, a gymnosperm, which appears to be connected with both cycads and conifers.

In the Carboniferous period, which, taken as a whole, has been termed the "Age of Acro-

¹ "Floras of the Past," Address to Botanical Section, Brit. Assoc., 1903.

gens," there was an abundant flora consisting principally of tree-ferns and rhizocarps, of lycopods and club-mosses (such as *Lepidodendron* and *Sigillaria*), and of equisetaceæ (such as *Calamites*). Representatives of these groups are characteristic of the Coal-measures.

In the Permo-Carboniferous the fern *Glossopteris* is characteristic, and it is associated with *Gangamopteris*. *Voltzia* and other conifers also occur.

The Secondary era is characterised by the abundance of cycads and conifers, and has been termed the "Age of Gymnosperms," and sometimes the "Age of Cycads." As remarked by Professor Seward, "The vegetation maintained a striking uniformity of character, from the close of the Triassic up to the dawn of the Cretaceous era."

The Tertiary era has been classed as the "Age of Angiosperms," but many forms came earlier into existence and characterise the Upper Cretaceous, and Dr. M. C. Stopes has lately obtained evidence of specimens from the Lower Cretaceous of Northern Europe.

It is impossible to deal with the history of the discovery of the many groups of fossils, and allusion can only be made to some of the more remarkable vertebrate remains not previously mentioned.

The discoveries in the newer Tertiary and

Quaternary strata of the Argentine Republic include, among many other mammalia, the gigantic sloth *Megatherium* and the giant armadillo *Glyptodon*, described by Owen as having a tessellated trunk-armour five feet in length.

In the Lower Pliocene of the Siwalik Hills in India, Dr. Hugh Falconer and Sir Proby T. Cautley in 1831 obtained remains of *Sivatherium* (allied to the giraffes), the largest known tortoise, *Colossochelys atlas*, about eight feet in length, and other vertebrata.

ALBERT GAUDRY (1827-1908), for many years Professor of Palæontology at the Museum of Natural History in Paris, and distinguished for his researches on the vertebrata, obtained during the years 1855-60 a varied assemblage of Lower Pliocene mammalia from Pikermi to the north-east of Athens. They included *Mastodon*, *Dinotherium*, *Helladotherium* (allied to the giraffes), *Machærodus* (sabre-toothed tiger), etc.¹

Admiral T. A. B. Spratt obtained in 1860, from caves in Malta, remains of a pigmy elephant, *Elephas melitensis*, of Pleistocene age. A pigmy hippopotamus has likewise been found.


During recent years many notable remains, including primitive types of elephant, have been obtained from the Upper Eocene and Lower

¹ See also A. Smith Woodward, *Geol. Mag.*, 1901, p. 48.

Oligocene strata of the Fâyum in Egypt by Mr. H. J. L. Beadnell and Dr. C. W. Andrews.

The United States has not been behindhand in yielding remains of remarkable vertebrates. Joseph Leidy (1823-1891) obtained many forms; and he was followed by O. C. Marsh (1831-1899), E. D. Cope (1840-1897), and more recently by Professor H. F. Osborn. From the Tertiary, Cretaceous, and Jurassic strata of Kansas, Colorado, Wyoming, and Utah, there have been obtained in the course of years numerous new genera of saurians, birds, and mammals, some of huge dimensions and extraordinary characters. Among herbivorous dinosaurs the *Diplodocus* from the Jurassic strata of Wyoming was about eighty feet in length. The *Pteranodon*, a toothless flying reptile or pterodactyl, with wings about twenty feet in expanse, was obtained from the reddish and bluish chalk of Kansas. In that and some other regions the vertebrate remains occur in strata that are exposed over wide areas almost destitute of vegetation, except for desert shrubs that fix their roots in the rock-crevices. With a scarcity of good water, the collecting of the fossils has proved a most arduous and exhausting task; it was largely carried out by Mr. Charles H. Sternberg, whose reminiscences are full of interest.¹

¹ See Sternberg (1909).



The famous "Homo diluvii testis" of Scheuchzer, discovered in 1700, in the upper fresh-water Molasse of Miocene age, at Oeningen, between Constance and Schaffhausen, was (as remarked by Lyell) "afterwards demonstrated by Cuvier to be a reptile, or aquatic salamander, of larger dimensions than even its great living representative, the salamander of Japan." The supposed "fossil man" is preserved in the Teyler Museum, at Haarlem, under the name *Cryptobranchus scheuchzeri*.

Schmerling, who during the years 1833-34 investigated the caverns along the Meuse valley near Liège, found bones of man in the same condition as remains of cave-bear, hyæna, elephant, and rhinoceros. He concluded that man was contemporaneous with the cave-bear, but he was in doubt whether the mammoth, hyæna, and other beasts supposed to indicate a warmer climate, could have existed at the time.¹

It is noteworthy that in 1785 remains of hippopotamus were recorded from the "drift or river sand," at a depth of twelve feet, at Chatham, by the Rev. James Douglas, who concluded that "this animal was the inhabitant of these regions when in a state of climature to have admitted of its existence."²

Researches in caverns and on the organic

¹ Lyell, *Antiquity of Man*, ed. 4, 1873, p. 69.

² *A Dissertation on the Antiquity of the Earth*, 1785, p. 11.

remains found in them were carried on at an early date last century by Buckland, and subsequently by William Pengelly and others. Until 1903, when Professor W. Boyd Dawkins obtained remains of *Mastodon*, *Elephas meridionalis*, and other vertebrata from near Buxton, no Pliocene remains had been recorded from any British cavern.

As in the case of some other discoveries, flint implements, the work of man in prehistoric times, were found long before their significance was manifest. Until Sir John Evans called attention to the fact that some implements of Palæolithic type from Hoxne, in Suffolk, were figured by John Frere in a paper read before the Society of Antiquaries in 1797, the matter had been overlooked for sixty years.

In 1849 Boucher de Perthes (1788-1868) figured and described many rudely-worked flint implements which he had found three years previously in some undisturbed beds of gravel in the valley of the Somme at Amiens and Abbeville. His views, however, received little attention, but, as Huxley remarked, the author had not made out his case.¹

Hugh Falconer, who went to Abbeville in November, 1858, saw De Perthes and his collection, and was so impressed by the evidence

¹ Obit. notice in Address to Geol. Soc., 1869.

Palæontology. Succession of Life 177

that he urged Prestwich to go and see the specimens and examine the district. Prestwich accordingly went to Abbeville in April, 1859, and satisfied himself that the flint implements were the work of man, that they were found in undisturbed ground, and that they were associated with the remains of extinct mammalia.

From that date researches on the valley gravels, their mammalian remains, and flint implements were carried out in various regions; and it came to be admitted that man must have existed on the earth far longer than was admitted in Biblical chronology.

The age could not be expressed in years; it was regarded as relative, to be judged by the excavation of valleys, the formation of deposits, and by changes in physical conditions, and in the fauna and flora.

So far as our present knowledge goes, it may be considered that man certainly lived as far back as the commencement of the Pleistocene period, and possibly came into existence in the Pliocene.

The History of Anthropology is separately treated by Dr. A. C. Haddon.

CHAPTER VIII

THE ARCHÆAN AND METAMORPHIC ROCKS. GREAT EARTH MOVEMENTS. PETROLOGY. CONCLUDING REMARKS

THE "foundation-stones of the Earth's Crust," as they have been termed by Professor Bonney, consist of a complex of highly-altered volcanic, plutonic, and sedimentary rocks; of gneisses, mica-schists, hornblende-schists, quartz-schists, saccharoidal lime-stones, dolomites, and other more or less crystalline rocks. None of them, according to Professor Michel Lévy, can be regarded as actually primitive or original. Geological history may be said to have been well established in the Archæan era; but in all attempts to trace the history further back we enter the speculative regions of Cosmogony, a subject to which brief reference is made by Professor George Forbes in his *History of Astronomy*.

The origin of the crystalline, schistose, or foliated rocks has been discussed by many observers in this country and abroad, by Scrope,

Darwin, Daniel Sharpe, and others; but the nature of the rocks was not understood until it was discerned that the structural features were largely brought about by the combined effects of great earth movements and of intrusive masses of igneous rock, leading to regional and contact metamorphism: the disturbances and plications being accompanied by differential movements causing deformation and recrystallisation of rock-masses by mechanical and chemical agencies. The cleavage in slates was shown by Sedgwick in 1835 to be a structure independent of stratification, and due to the effects of enormous force on shaly rocks of comparatively uniform character. On a complicated series of rocks of different textures and composition, the results of great and successive disturbances such as those manifested during the processes of mountain-building, produced the schistose rocks; and Karl August Lossen (1841-1893) has been spoken of as the founder of the modern views of dynamo-metamorphism.

The processes which led to the production of these highly metamorphic Archæan rocks have been repeated during later periods of great disturbance, so that there are schists of various ages, some of them being found to pass into less altered rocks, the age of which can be determined by fossil evidence.

The first important essay on the general

structure of mountain-chains was that by Élie de Beaumont (1798–1874), published in 1829, but enlarged and modified from time to time, and finally published as *Notices sur les Systèmes de Montagnes* in 1852. He dealt with the prevalent directions of the European ranges and with the periods of disturbance, concluding that certain chains were upheaved suddenly and along lines that were more or less parallel when contemporaneous. As regards the Alps, he came to recognise that they were upheaved several thousand feet in places during the Tertiary period; and, as regards the Pyrenees, at first attributed by him to one great convulsion, he afterwards saw reason to believe in several stages of upheaval. He maintained that in the history of the earth there were long periods of comparative repose, and shorter periods of great disturbance; and that the periods of elevation were accompanied or followed by changes in the organic remains.¹

Sir John Herschel in 1837 suggested that the accumulation of sediment to a great depth over large areas would cause subsidence,² and this view has since attracted much attention, it being considered that denudation would similarly lead to elevation.

The brothers W. B. and H. D. Rogers, in 1842,

¹ See p. 166.

² *Proc. Geol. Soc.*, ii., p. 50.

were among the first to describe the great folds and dislocations of rocks in the Appalachian chain, whereby older strata were "shoved over" newer, in the form now known as overthrusts.

In the Alpine regions many workers, among them Alphonse Favre (1815-1890), Professor of Geology at Geneva, have laboured to elucidate the main structures.*

To Professor ALBERT HEIM, whose great work, *Mechanismus der Gebirgsbildung*, was published in 1878, we are indebted for detailed illustrations and interpretations of the wonderful plactions, overthrusts, and "fan-like" arrangements that enter into the structure of the Alps.

In parts of the mountainous region of Sutherland there appeared to be a sequence upwards from the Fundamental or Archæan gneiss, of lower quartzite, Durness limestone, and upper quartzite, passing into a newer series of flaggy gneisses and schists. If the interpretation were correct, as held by Murchison, it had a most important bearing on the age of the great mass of the Highland schists, and of their metamorphism.


James Nicol (1810-79), whose views, after long and arduous labour, were matured in 1859, was the first to perceive that the supposed succession was caused, not by the ordinary

* See Suess (1909), vol. iv., p. 104.

processes of deposition, but by great foldings and displacements, whereby older rocks had been forced over newer along planes of dislocation or overthrow faults. The researches of Professor Lapworth in 1882 supported those of Nicol in the more essential points, and were confirmed and amplified by the subsequent detailed work of the Geological Survey, carried out by Messrs. B. N. Peach, J. Horne, and others, so that in 1884 Sir Archibald Geikie was able to acknowledge that the sequence for which Murchison had contended was no longer tenable. Thus came to an end a great geological combat which, like the Cambro-Silurian controversy, had been carried on for some time with considerable warmth.

The petrology of the igneous rocks has the advantage of being a more exact science than that of palæontology. The materials consist of crystalline aggregates of distinct minerals, and, although in composition the rocks vary and pass gradually one into another, yet the constituents can be defined. By the earlier geologists and mineralogists the names adopted were those commonly in use locally, or by merchants who supplied stone, such as granite, syenite, porphyry, basalt, serpentine, elvan (in Cornwall), toadstone (in Derbyshire), and felstone (feldstein, as used by the German miners of Nassau).

The term trap, introduced in Sweden by



Bergman, came generally to be applied to the greenstones, as distinct from the granites.

This broad division of igneous rocks was considered, in 1851, by Bunsen to be due to the derivation of the materials from two distinct magmas—a view more fully developed by Durocher (1817–1858) in 1857.¹ From their researches igneous rocks came to be divided into the acid and basic, the former containing more than sixty per cent. of silica, and including granite, syenite, trachyte, pitchstone, etc.; the latter containing under sixty per cent. of silica, and including gabbro, diorite, basalt, dolerite, etc. Rocks of an intermediate type, such as andesites and porphyrites, were regarded as “due to the intermixture of the two magmas at the zone of contact.” Other rocks, termed ultra-basic by rosenbusch, include peridotite and serpentine.

As early as 1822, and following some investigations made by Brewster, minute cavities holding fluids were detected in crystals by Humphry Davy; but it was not until 1857 that the subject was investigated in detail, and then H. C. SORBY (1826–1908) read before the Geological Society of London his classic memoir on the Microscopic Structure of Crystals, and gave calculations to determine the pressure and consequent

¹ See Teall, *British Petrography*, 1888, p. 44.

depth under which granite was consolidated. The work which he then initiated, and his subsequent researches on igneous and sedimentary rocks, led to his being designated as "the Father of Microscopical Petrography."¹

The researches of J. H. L. Vogt in 1891 on the concentration of iron-ores from igneous magmas, and their dispersal among the rocks by various processes, have greatly advanced knowledge, not only of the origin of iron-ores, but of the order of crystallisation of minerals during the consolidation of igneous magmas.

Suess, who in 1885 introduced the term Batholite for great intrusive masses chiefly of granite, such as those of Devon and Cornwall, at first was of opinion that they had filled cavities due to disturbance; in a later discussion on the subject (1909) he considers that batholites have reached their present position by melting and absorbing the adjacent rock. Few petrologists have adopted this view of assimilation.

The great lenticular masses of igneous rock that have been intruded among various formations were described as laccolites by Mr. G. K. Gilbert.² They may in some cases have been the immediate cause of disturbance; in others they may have occupied cavities already pro-

¹ See Obituary by J. W. Judd, *Geol. Mag.*, 1908, p. 193.

² *Geology of the Henry Mountains*, 1877.

duced. The deeper-seated igneous rocks, as pointed out by Dr. A. Harker, have played a more important part in the structure of the earth's crust than the outpourings of lava and other volcanic materials.

Concluding Remarks

The fascinating subject of earth sculpture has attracted attention at all times, notably since the days of Hutton and Playfair. The subject is by no means a purely geographical one, of processes now in action. Ancient features are revealed here and there by the agents of denudation, as in the rugged, but not very prominent, surfaces of Lewisian gneiss beneath the Torridon sandstone. Sir A. W. Rücker in 1890 suggested that magnetic observations might indicate the proximity of underground igneous rocks containing magnetite, and Suess has drawn attention to "invisible mountains," the presence of which is indicated by deflection of the plummet.

An instance of a nearly buried mountain-mass is that of the Charnwood Forest area, where, amid pastoral scenery formed mostly of Keuper marls, there protrude, as Professor W. W. Watts has pointed out, the veritable peaks and arêtes of a mountain system, formed of Pre-Cambrian slates, hornstones, and agglomerates, with intruded granites and syenites.

He found evidence also on the rocks of Mount Sorrel of wind-erosion that took place in the Triassic deserts before the peaks were buried under the Keuper marls.

Space prevents our entering into the history of the views on modern agents of erosion, on the relative powers of sea, rivers, glaciers, and minor agents.

Suess, who considers that dislocations of great magnitude have resulted from contraction of the volume of the earth, has discussed very fully the main features of land and water, and the origin of mountain and ocean basin.

To what extent raised beaches and submerged forests and rock-platforms may have been due to fluctuations in the level of the sea has also been discussed by Suess and others. There is, however, no general disposition among geologists to abandon the view that there have been many Pleistocene and Recent movements of the terrestrial crust.¹

So far as known, all countries, including Polar regions, exhibit evidence of great changes in physical conditions and climate; and among the more notable of recent discoveries has been the evidence of glaciation in Pre-Cambrian, Cambrian, Devonian, and Permo-Carboniferous times.

¹ See Sir A. Geikie, Address to Geol. Soc., London, 1904.

There is no doubt, as urged by James Croll, that the influence of ocean currents is of great importance, and that uplifts and depressions, changing the distribution of land and water, had a potent effect on climates. The influence of winds upon climate during the Pleistocene period was ably discussed by Mr. F. W. Harmer in 1901.

The revolution of the solar system may have led to some alteration in climatic conditions; but suggestions that there has been shifting of the earth's axis are not accepted at the present day. Some climatic variations may have been caused by the amount of carbonic acid gas in the atmosphere—a view supported by Prestwich, and more recently by Professor Chamberlin.¹

With regard to geological time much has been written, but little need here be said. The immensity is indicated by the great, and for the most part gradual, changes in scene and life of which geology furnishes the records.

Huxley in 1869 expressed his opinion that one hundred million years would satisfy the reasonable demands of the geologist so far as the Palæozoic and newer strata were concerned, the rate of deposition being estimated at about one eighty-third of an inch per annum for a thickness of 100,000 feet of sediment.

¹ *Journ. Geol.* (Chicago), v., 1897, p. 653.

More recent reckonings, based on the origin of the saline ingredients in the ocean, and especially on the amount of sodium chloride brought annually into it by rivers, have led Professor J. Joly and Professor W. J. Sollas¹ to frame estimates of about eighty or ninety million years for the known sedimentary series. These data are admittedly speculative, and opinions differ with regard to the amount of sodium chloride in the primitive ocean. The total thickness of the sedimentary formations from the Huronian (Pre-Cambrian) was calculated at 335,800 feet, and the rate of deposition at about one foot in a century.

The researches of the Hon. R. J. Strutt on radium and helium, however, tend to give a far higher antiquity to the earth, as he computes a period of about seven hundred million years from Archæan times.²

We may safely regard the period of geological time as vast, but the reckoning of geological ages into any exact number of years is at present beyond our ken.

¹ Address to Geol. Soc., London, 1909.

² *Proc. Roy. Soc.*, 1910, Ser. A., lxxxiv., p. 194.

BIBLIOGRAPHY

[Exigencies of space have prevented acknowledgment in a Preface of the publications to which the author has been more especially indebted; but some are recorded in the subjoined lists, and others are noted in the text and footnotes, occasionally with references by date to these lists. In addition to the biographies noted below, others have been published on L. Agassiz, Cuvier, Dana, Darwin, E. Forbes, Huxley, Jukes, Lesley, Logan, Owen, Pengelly, Prestwich, Ramsay, W. B. Rogers, Sopwith, Strickland, Whewell, etc.]

D'Archiac. *Histoire des Progrès de la Géologie de 1834-59*. Paris, 1847-60.

Bonney, Professor T. G. *Charles Lyell and Modern Geology*. London, 1901.

Chamberlin, T. C., and R. D. Salisbury. *Geology*. Three vols. London, 1905-06.

Clark, J. W., and T. McK. Hughes. *Life of the Rev. A. Sedgwick*. Two vols. Cambridge, 1890.

Clodd, E. *Story of Creation*. London, 1906.

Conybeare, Rev. W. D. *Report on the Progress of Geological Science*. (Brit. Assoc. for 1832.)

Fitton, W. H. *Notes on the Progress of Geology in England.* (Edin. Phil. Mag.) 1833.

Geikie, Sir A. *Life of Sir R. I. Murchison.* Two vols. London, 1875.

—*Text-Book of Geology.* Ed. 4. Two vols. London, 1903.

—*Founders of Geology.* Ed. 2. London, 1905.

Gordon, Mrs. *Life of W. Buckland.* London, 1894.

Harker, A. *Natural History of Igneous Rocks.* London, 1909.

Hutchinson, Rev. H. N. *Extinct Monsters and Creatures of Other Days.* London, 1910.

Keferstein, C. *Geschichte und Litteratur der Geognosie.* Halle, 1840.

Kobell, F. von. *Geschichte der Mineralogie von 1650–1860.* Munich, 1864.

Lankester, Sir E. R. *Extinct Animals.* London, 1909.

Lapparent, A. de. *Traité de Géologie.* Ed. 5. Paris, 1906.

Lyell, Mrs. *Life of Sir C. Lyell.* Two vols. London, 1881.

Margerie, E. de. *Catalogue des Bibliographies Géologiques.* Paris, 1896.

Merrill, G. P. *History of American Geology.* Washington, 1906.

Miers, H. A. *Mineralogy.* London, 1902.

Nicholson, H. A., and R. Lydekker. *Manual of Palaeontology*. Ed. 3. Two vols. London, 1889.

Phillips, J. *Memoirs of Wm. Smith*. London, 1844.

Ramsay, A. C. *Passages in the History of Geology*. London, 1848 and 1849.

Rudler, F. W. *Fifty Years' Progress in British Geology* (*Proc. Geol. Assoc.*, x., 1888).

—*Experimental Geology* (*ibid.*, xi., 1889).

Schvarcz, J. *The Failure of Geological Attempts made by the Greeks*. Ed. 2. London, 1868.

Sollas, W. J. *Age of the Earth, and other Geological Studies*. London, 1905.

Sternberg, C. H. *Life of a Fossil Hunter*. London, 1909.

Suess, E. *Das Antlitz der Erde*. Four vols. Vienna, 1885–1909. (English ed. by H. B. C. Sollas, 1904–9.)

Topley, W. *The National Geological Surveys of Europe*. (*Brit. Assoc.*) 1885.

Whewell, Rev. W. *Report on the Progress of Mineralogy* (*Brit. Assoc.* for 1832).

—*History of the Inductive Sciences* (London, 1837; ed. 3, 1857).

Williams, H. S. *Correlation of Geological Faunas*. (*U. S. A. Geol. Survey, Bulletin 210.*) Washington, 1903.

Willis, B., and R. D. Salisbury. *Outlines of*

Geologic History, with especial reference to North America. Chicago, 1910.

Woods, H. *Palæontology Invertebrate.* Ed. 3. London, 1902.

Woodward, Dr. A. Smith. *Outlines of Vertebrate Palæontology.* Cambridge, 1898.

Woodward, B. B. *Catalogue of the Books, etc., in the British Museum (Nat. Hist.).* Three vols. London, 1903-10.

Woodward, H. B. *History of the Geological Society of London.* London, 1907.

Young, R. B. *Life of G. W. Stow.* London, 1908.

Zittel, K. A. von. *Geschichte der Geologie und Paläontologie,* Munich, 1899. (English ed. by M. M. Ogilvie-Gordon. London, 1901).

INDEX

[Mainly of authors. Where an author or subject is mentioned on consecutive pages, only the first reference is given.]

	PAGE
Abich, O. W. H. von	117
Agassiz, L. 20, 31, 92, 140,	152
Agricola, G.	9
Alberti, F. von	145
Andrews, C. W.	174
Angelin, N. P.	137
Anning, M.	82
Archæan	166, 178
Archiac, Vicomte d'	109, 158
Arduino	19
Aristotle	4
Atherstone, W. G.	120
Aubrey, J.	11
Aubuisson, J. F. d'	64, 78
Avicenna	7
 Bain, A. G.	 120
Bakewell, R.	64
Ball, Sir R.	17
Barrande, J.	133
Barrois, C.	149
Beadnell, H. J. L.	174
Benett, E.	161
Berger, J. F.	60
Bergman, T. O.	183
Beyrich, H. E.	153
Bigsby, J. J. 60,	152
Blainville, H. M. D. de	92
Bonney, T. G.	178
Boucher de Perthes	176

	PAGE
Boué, A.	40, 73, 76
Bournon, Count de.	57
Brander, G.	23
Breislak, S.	64
Brewster, Sir D.	183
Brocchi, G. B.	70
Brochant de Villiers.	116
Broderip, W. J.	92
Brongniart, Ad.	95, 170
Brongniart, Alex.	55, 64, 89, 135, 152
Bronn, H. G.	158
Buch, L. von.	40, 76, 78
Buckland, W.	10, 60, 73, 82, 85, 90, 92, 97, 109, 114, 138, 152, 169, 176
Buffon.	21
Bunsen, R. W. E. von.	183
Burnet, T.	17
Cainozoic.	149
Callaway, C.	135
Cambrian.	126
Carboniferous.	101, 107, 143
Catastrophists.	100
Catcott, A.	39
Cautley, Sir P. T.	173
Cavern researches.	175
Chamberlin, T. C.	67, 166, 187
Chronological divisions.	163
Clark, J. W.	16
Clarke, E. D.	61
Clarke, W. B.	121
Cleavage, slaty.	179
Climatic changes.	12, 107, 175, 186
Colby, T. F.	112
Conrad, T. A.	95, 118
Conybeare, J. J.	59, 61
Conybeare, W. D.	10, 21, 29, 60, 74, 82, 88, 96, 98, 103, 107, 138, 143, 152
Cope, E. D.	174
Costa, E. M. da.	23
Credner, C. F. H.	149
Cretaceous.	93, 148
Croll, J.	187
Crystallography.	56

Index

195

	PAGE
Cuvier	29, 32, 52, 75, 89, 92, 94, 175
Dahll, T.....	117
Dall, W. H.....	150
Dana, E. S.....	109
Dana, J. D.....	109
Darwin, C.....	168, 179
Daubeny, C. G. B.....	60, 80
Daubrée, G. A.....	41
Davy, Sir H.....	57, 81, 183
Dawkins, W. B.....	125, 176
Dawson, Sir J. W.....	166, 170
Dechen, H. von.....	116, 143
De la Beche, Sir H. T....	60, 74, 89, 103, 109, 114, 124
Delesse, A.....	41
De Luc, J. A.....	25, 32, 152
Deluge.....	8, 9, 15, 17, 39, 85, 154
Denudation.....	39, 81, 84
Deshayes, G. P.....	105, 150
Deslongchamps, J. A. L.....	93
Desmarests, N.....	22
Devonian.....	128, 143, 165
Dewalque, G.....	143
Diastrophism.....	166
Dick, R.....	140
Diluvial.....	84, 87, 100, 151
Diodorus Siculus.....	5
Dolomieu.....	36
Douglas, J.....	175
Dumont, A. H.....	117, 143, 150
Dupont, E.....	118
Durocher, J. M. E.....	183
Dufrénoy, P. A.....	116
Du Toit, A. L.....	121
Earth-movements.....	78, 84, 179, 186
Earthquakes.....	22, 88, 100
Earth, theories of the.....	15, 21, 35
Eastman, C. R.....	170
Eaton, A.....	118
Economic geology.....	70, 123, 155
Egerton, Sir P. de M. G.....	140
Ehrenberg, C. G.....	171
Eichwald, C. E. von.....	117

	PAGE
Élie de Beaumont.....	76, 116, 180
Emmons, E.....	118, 134
Eocene.....	105, 150
Eozoic.....	167
Erdmann, A. J.....	117
Escher, von der Linth.....	117
Evans, Sir J.....	176
Evolution.....	5, 53
Experimental geology.....	25, 40
Falconer, H.....	173, 176
Farey, J.....	71
Faujas de St. Fond.....	22, 28
Favre, A.....	181
Fischer de Waldheim, G.....	156
Fitton, W. H.....	60, 80, 91, 149
Flint implements.....	176
Floetz groups.....	33
Flood. <i>See</i> Deluge <i>and</i> Diluvial.	
Flower, Sir W. H.....	110
Foliation.....	178
Footprints.....	146
Forbes, E.....	78, 150
Forbes, G.....	178
Formations.....	24, 33, 49, 51, 106, 162, 164
Fossils, early notions about.....	4, 6, 9, 12, 27, 52, 88
distribution of.....	19, 24, 83, 107, 164, 168
strata identified by.....	44, 49, 68, 75, 78, 163
from Drift.....	50, 68, 86
Fouqué, F. A.....	41
Frascaturo.....	8
Frere, J.....	176
Füchsel, G. C.....	24
Gardner, J. S.....	151
Gaudry, A.....	173
Gay-Lussac, J. L.....	81
Geikie, Sir A.....	22, 25, 38, 52, 76, 90, 154, 182, 186
Geikie, J.....	154
Geinitz, H. B.....	149
Geoffroy-St.-Hilaire.....	93
Geognosy.....	33, 64
Geological record, imperfection of.....	168
Geological Society of London.....	58

	PAGE
Geological Surveys.....	22, 112
Geological systems.....	126
Geological time.....	12, 100, 187
Geology, birth and objects of.....	1, 12, 25, 32, 98, 110
great masters of.....	58, 75
Gesner, C.....	9
Gilbert, G. K.....	184
Giordano, F.....	118
Glacial period.....	100, 107, 152
Glaciation in earlier epochs.....	186
Godwin-Austen, R. A. C.....	124, 141
Goldfuss, G. A.....	70
Gosselet, J.....	143
Granite.....	38, 74, 102, 182
Grant, R. E.....	92
Grauwacke. <i>See</i> Greywacke	
Greenly, E.....	7
Greenough, G. B.....	58, 73
Greenstones.....	183
Gregory, J. W.....	165
Greywacke.....	34, 103, 126, 128
Griffith, Sir R. J.....	67
Guettard, J. E.....	21
Gümbel, C. W. von.....	117, 146
Haast, J. von.....	122
Haddon, A. C.....	177
Haidinger, W. von.....	116
Hall, Sir J.....	40, 152
Hall, J.....	118, 134, 160
Hargraves, E. H.....	121
Harker, A.....	185
Harmer, F. W.....	187
Hauer, F. R. von.....	116
Haüy, R. J.....	56, 64
Hayden, F. V.....	119
Hébert, E.....	149
Hector, Sir J.....	122
Heim, A.....	181
Helmersen, G. von.....	117
Henslow, J. S.....	60
Herodotus.....	4
Herschel, Sir J. F. W.....	180
Hicks, H.....	135

	PAGE
Highland succession.....	181
Hinde, G. J.....	161
Hitchcock, E.....	119, 147
Hochstetter, F. von.....	122
Hoernes, M.....	151
Hoff, K. E. A. von.....	96
Hoffman.....	28
Holocene.....	151
Home, Sir E.....	81
Hooke, R.....	12
Horne, J.....	182
Horner, L.....	60
Howorth, Sir H. H.....	30
Hughes, T. McK.....	16, 132
Humboldt, A. von.....	76, 78
Hutton, F. W.....	122
Hutton, J.....	32, 35, 75, 81, 96, 185
Hutton, W.....	170
Huttonians.....	59, 80
Huxley, T. H.....	147, 168, 176, 187
Ice-sheets.....	153
Ichnology.....	147
Igneous rocks.....	36, 182
Infusorial earths.....	171
Jameson, R.....	40, 59, 62, 73
Joly, J.....	188
Judd, J. W.....	68, 113, 184
Jukes-Browne, A. J.....	149
Jurassic.....	80, 148, 168
Kaup, J. J.....	93
Kayser, E.....	134, 143
Keyserling, von.....	117
Kidd, J.....	59, 85
King, C.....	119
Kirwan, R.....	40
Kitchin, F. L.....	21, 160
Kjerulf, T.....	117
Klein, J. T.....	23
Koenig, C.....	82
Koninck, L. G. de.....	144
Kotô, B.....	120

Index

199

	PAGE
Lamarck.....	40, 52, 167
Lapworth, C.....	130, 133, 182
Laurentian.....	166
Lehmann, J. G.....	18
Leibnitz.....	16, 21
Leidy, J.....	174
Leland.....	19
Leske, N. G.....	24
Lévy, M.....	178
Lewis, T. T.....	129
Lhwyd, E.....	13, 50
Life, dawn of.....	136, 167
Lindley, J.....	170
Lindström, G.....	138
Linnæus.....	20
Linnarsson, J. G. O.....	137
Lister, M.....	11
Logan, Sir W. E.....	115
Lonsdale, W.....	90, 141
Lossen, K. A.....	179
Lucretius.....	5
Lyell, Sir C.....	20, 30, 41, 60, 64, 76, 94, 96, 114, 138, 147, 150, 175
McClelland, J.....	115
McCoy, Sir F.....	121
MacCulloch, J.....	60, 74, 113
Maclure, W.....	66
Magnesium limestone.....	144
Man, antiquity of.....	177
Mantell, G. A.....	60, 93, 109, 147
Maps, early geological.....	11, 12, 21, 22, 46, 66, 67, 73
later geological and topographic.....	112
Marcou, J.....	119
Marr, J. E.....	134, 165
Marsh, O. C.....	147, 174
Martin, P. J.....	95
Maton, W. G.....	26
Meneghini, G.....	118
Menevian.....	135
Merrill, G. P.....	66, 110, 119, 136
Mesozoic.....	145
Metallurgy.....	9
Metamorphism.....	179

	PAGE
Michell, J.....	24
Miller, H.....	138
Miller, J. S.....	89
Mineralogy.....	7, 9, 20, 34, 56, 76, 109
Miocene.....	105, 150
Mohs, F.....	64
Mojsisovics, E. von.....	146
Morlot, A.....	150
Mountains.....	180
buried.....	185
Münster, G.....	70
Murchison, Sir R. I.....	41, 54, 60, 75, 90, 117, 121, 126, 128, 138, 141, 144, 152, 181
Naumann, C. F.....	109
Neogene.....	151
Neptunists.....	34, 40
Neumayr, M.....	168
Newberry, J. S.....	119
New Red Sandstone.....	144
Nicol, J.....	181
Nilsson, S.....	95
Nomenclature, Palæontological.....	20, 24
Oldham, T.....	115
Old Red Sandstone.....	138
Oligocene.....	106, 150
Omalius d'Halloy.....	76, 109
Omar Khayyám.....	7
Oppel, A.....	148
Orbigny, A. d'.....	109, 156, 163
Ordinance survey.....	114
Ordovician.....	133
Organic remains. <i>See</i> Fossils.	
Oryctology.....	88
Osborn, H. F.....	174
Otley, J.....	128
Overthrusts.....	181
Owen, G.....	10
Owen, Sir R.....	92, 120, 140, 158, 173
Owen, R. D.....	119
Packe, C.....	21
Palæolithic implements.....	176

	PAGE
Palaeontographical society.....	69, 161
Palaeontology.....	52, 156
Palaeozoic.....	104, 145
Palissy, B.....	9
Pallas, P. S.....	29
Pander, C. H.....	95
Park, J.....	122
Parkinson, J.....	57, 88
Pattison, S. R.....	141
Peach, B. N.....	182
Peach, C. W.....	142
Pengelly, W.....	142, 176
Permian.....	144
Petrology.....	74, 182
Phillips, J.....	44, 51, 61, 145, 149, 160
Phillips, W.....	58, 73, 82, 88
Pictet, F. J.....	158
Playfair, J.....	38, 59, 80, 185
Pleistocene.....	106, 151
Pliny (elder).....	5
Pliocene.....	105, 150
Plot, R.....	13, 50, 61
Plutonists.....	36
Portlock, J. E.....	62, 113
Powell, J. W.....	119
Pre-Cambrian.....	167
Prestwich, Sir J.....	99, 118, 150, 177, 187
Prevost, C.....	92
Primary.....	102
Primitive rocks.....	18, 34, 102
Pringle, J. W.....	113
Pythagoras.....	4
Quaternary.....	150, 151
Quenstedt, F. A. von.....	148
Raised beaches.....	186
Ramsay, A. C.....	99, 158
Ray, J.....	39
Recent.....	151
Reich, O.....	97
Reid, C.....	151
Renévier, E.....	164
Rhætic.....	146

	PAGE
Richardson, B.....	45, 50
Richardson, Sir J.....	31
Rocks.....	74, 182
Roemer, C. F. von.....	149
Roemer, F. A.....	143, 149
Rogers, A. W.....	121
Rogers, H. D.....	180
Rogers, W. B.....	180
Romé de l'Isle.....	56
Rouelle, G. F.....	19
Rowe, A. W.....	149
Rücker, Sir A. W.....	185
Rudler, F. W.....	41
St. Claire-Deville, C. J.....	41
Salisbury, R. D.....	67, 167
Salter, J. W.....	135
Sandberger, G. and F.....	143
Saussure, H. B. de.....	25, 32, 40
Savi, P.....	118
Scheuchzer, J. J.....	175
Schists.....	178
Schlotheim, E. F. von.....	70
Schmerling, P. C.....	175
Schvarcz, J.....	4
Scrope, G. P.....	60, 81, 178
Sea-level, changes of.....	84, 186
Secondary.....	19, 33, 55, 101
Sedgwick, A.....	16, 51, 60, 75, 83, 86, 98, 108, 114, 126, 141, 145, 162, 179
Serres, Marcel de.....	95
Sessa, F.....	13
Seward, A. C.....	171
Shaler, N. S.....	140
Sharp, S.....	124
Sharpe, D.....	179
Sherborn, C. D.....	158
Silurian.....	126
Smith, W.....	26, 32, 42, 46, 55, 60, 64, 68, 71, 148
Soil-maps.....	154
Solander, D. C.....	23
Sollas, W. J.....	62, 154, 188
Sopwith, T.....	71
Sorby, H. C.....	183

	PAGE
Sowerby, J.....	60, 68
Sowerby, J. de C.....	68
Species, development of.....	20, 108
migration of.....	134
recurrence of.....	134
Spratt, T. A. B.....	173
Steno, N.....	10
Sternberg, C. H.....	174
Sternberg, K. von.....	170
Stopes, M. C.....	172
Stoppani, A.....	109
Stow, G. W.....	120
Strabo.....	5
Strachey, J.....	42
Strata. <i>See</i> Formations.	
Stratigraphy, early views on.....	10, 18, 24
Strutt, Hon. R. J.....	188
Strzelecki, P. E. de.....	121
Studer, B.....	109, 117
Stukeley, W.....	22
Subapennine fossils.....	70
Submerged forests.....	186
Suess, E.....	87, 88, 181, 184
Tables of Strata.....	45, 73, 101, 164
Taconic.....	136
Teall, J. J. H.....	99
Tertiary.....	19, 34, 89, 105, 150
Theophrastus.....	4
Tiddeman, R. H.....	87
Torrential. <i>See</i> Diluvial.	
Torridon Sandstone.....	167
Townsend, Rev. J.....	25, 45, 50, 59, 72
Transition formations.....	33, 101, 102
Trap-rocks.....	19, 36, 40, 182
Trias.....	145, 186
Trigonometrical survey.....	112
Trimmer, J.....	150, 154
Uniformitarianism.....	99
Ussher, W. A. E.....	143
Valenciennes, A.....	92
Vallisneri, A.....	19

	PAGE
Verneuil, P. E. P. de.....	117
Vinci, Leonardo da.....	8
Vogt, C.....	105
Vogt, J. H. L.....	184
Volcanic phenomena.....	22, 35, 78, 80, 85, 100
Volcanic rocks.....	36, 182
Vulcanists.....	36, 40
Walcott, C. D.....	119, 123, 134, 167
Walcott, J.....	51
Walker, E.....	5
Warren, E.....	12
Waters, underground.....	88
Watts, W. W.....	185
Wealden.....	94, 149
Weaver, T.....	60
Webster, T.....	64, 89
Werner, A. G.....	33, 64, 70, 76
Wernerians.....	59, 80
Wheeler, G. M.....	119
Whewell, W.....	32, 56, 61, 83, 99
Whiston, W.....	17
Williams, H. S.....	165
Willis, B.....	166
Wollaston, W. H.....	69, 76
Wood, S. V.....	162
Wood, S. V., Jr.....	155
Woodward, A. S.....	168, 173
Woodward, H.....	169
Woodward, J.....	13, 37
Woodward, S.....	161
Xenophanes.....	4
Young, R. B.....	121
Zechstein.....	19, 34, 145
Zieten, C. H. von.....	95
Zittel, K. A. von.....	32, 156, 160
Zones.....	135, 144, 146, 149, 169

*A Selection from the
Catalogue of*

G. P. PUTNAM'S SONS



**Complete Catalogue sent
on application**

	PAGE
Élie de Beaumont.....	76, 116, 180
Emmons, E.....	118, 134
Eocene.....	105, 150
Eozoic.....	167
Erdmann, A. J.....	117
Escher, von der Linth.....	117
Evans, Sir J.....	176
Evolution.....	5, 53
Experimental geology.....	25, 40
Falconer, H.....	173, 176
Farey, J.....	71
Faujas de St. Fond.....	22, 28
Favre, A.....	181
Fischer de Waldheim, G.....	156
Fitton, W. H.....	60, 80, 91, 149
Flint implements.....	176
Floetz groups.....	33
Flood. <i>See</i> Deluge <i>and</i> Diluvial.	
Flower, Sir W. H.....	110
Foliation.....	178
Footprints.....	146
Forbes, E.....	78, 150
Forbes, G.....	178
Formations.....	24, 33, 49, 51, 106, 162, 164
Fossils, early notions about.....	4, 6, 9, 12, 27, 52, 88
distribution of.....	19, 24, 83, 107, 164, 168
strata identified by.....	44, 49, 68, 75, 78, 163
from Drift.....	50, 68, 86
Fouqué, F. A.....	41
Frascatoro.....	8
Frere, J.....	176
Füchsel, G. C.....	24
Gardner, J. S.....	151
Gaudry, A.....	173
Gay-Lussac, J. L.....	81
Geikie, Sir A.....	22, 25, 38, 52, 76, 90, 154, 182, 186
Geikie, J.....	154
Geinitz, H. B.....	149
Geoffroy-St.-Hilaire.....	93
Geognosy.....	33, 64
Geological record, imperfection of.....	168
Geological Society of London.....	58

	PAGE
Geological Surveys.....	22, 112
Geological systems.....	126
Geological time.....	12, 100, 187
Geology, birth and objects of.....	1, 12, 25, 32, 98, 110
great masters of.....	58, 75
Gesner, C.....	9
Gilbert, G. K.....	184
Giordano, F.....	118
Glacial period.....	100, 107, 152
Glaciation in earlier epochs.....	186
Godwin-Austen, R. A. C.....	124, 141
Goldfuss, G. A.....	70
Gosselet, J.....	143
Granite.....	38, 74, 102, 182
Grant, R. E.....	92
Grauwacke. <i>See</i> Greywacke	
Greenly, E.....	7
Greenough, G. B.....	58, 73
Greenstones.....	183
Gregory, J. W.....	165
Greywacke.....	34, 103, 126, 128
Griffith, Sir R. J.....	67
Guettard, J. E.....	21
Gümbel, C. W. von.....	117, 146
Haast, J. von.....	122
Haddon, A. C.....	177
Haidinger, W. von.....	116
Hall, Sir J.....	40, 152
Hall, J.....	118, 134, 160
Hargraves, E. H.....	121
Harker, A.....	185
Harmer, F. W.....	187
Hauer, F. R. von.....	116
Hauy, R. J.....	56, 64
Hayden, F. V.....	119
Hébert, E.....	149
Hector, Sir J.....	122
Heim, A.....	181
Helmersen, G. von.....	117
Henslow, J. S.....	60
Herodotus.....	4
Herschel, Sir J. F. W.....	180
Hicks, H.....	137

	PAGE
Highland succession.....	181
Hinde, G. J.....	161
Hitchcock, E.....	119, 147
Hochstetter, F. von.....	122
Hoernes, M.....	151
Hoff, K. E. A. von.....	96
Hoffman.....	28
Holocene.....	151
Home, Sir E.....	81
Hooke, R.....	12
Horne, J.....	182
Horner, L.....	60
Howorth, Sir H. H.....	30
Hughes, T. McK.....	16, 132
Humboldt, A. von.....	76, 78
Hutton, F. W.....	122
Hutton, J.....	32, 35, 75, 81, 96, 185
Hutton, W.....	170
Huttonians.....	59, 80
Huxley, T. H.....	147, 168, 176, 187
Ice-sheets.....	153
Ichnology.....	147
Igneous rocks.....	36, 182
Infusorial earths.....	171
Jameson, R.....	40, 59, 62, 73
Joly, J.....	188
Judd, J. W.....	68, 113, 184
Jukes-Browne, A. J.....	149
Jurassic.....	80, 148, 168
Kaup, J. J.....	93
Kayser, E.....	134, 143
Keyserling, von.....	117
Kidd, J.....	59, 85
King, C.....	119
Kirwan, R.....	40
Kitchin, F. L.....	21, 160
Kjerulf, T.....	117
Klein, J. T.....	23
Koenig, C.....	82
Koninck, L. G. de.....	144
Kotô, B.....	120

	PAGE
Lamarck.....	40, 52, 167
Lapworth, C.....	130, 133, 182
Laurentian.....	166
Lehmann, J. G.....	18
Leibnitz.....	16, 21
Leidy, J.....	174
Leland.....	19
Leske, N. G.....	24
Lévy, M.....	178
Lewis, T. T.....	129
Lhwyd, E.....	13, 50
Life, dawn of.....	136, 167
Lindley, J.....	170
Lindström, G.....	138
Linnaeus.....	20
Linnarsson, J. G. O.....	137
Lister, M.....	11
Logan, Sir W. E.....	115
Lonsdale, W.....	90, 141
Lossen, K. A.....	179
Lucretius.....	5
Lyell, Sir C.....	20, 30, 41, 60, 64, 76, 94, 96, 114, 138, 147, 150, 175
McClelland, J.....	115
McCoy, Sir F.....	121
MacCulloch, J.....	60, 74, 113
Maclure, W.....	66
Magnesium limestone.....	144
Man, antiquity of.....	177
Mantell, G. A.....	60, 93, 109, 147
Maps, early geological.....	11, 12, 21, 22, 46, 66, 67, 73
later geological and topographic.....	112
Marcou, J.....	119
Marr, J. E.....	134, 165
Marsh, O. C.....	147, 174
Martin, P. J.....	95
Maton, W. G.....	26
Meneghini, G.....	118
Menevian.....	135
Merrill, G. P.....	66, 110, 119, 136
Mesozoic.....	145
Metallurgy.....	9
Metamorphism.....	179

	PAGE
Michell, J.....	24
Miller, H.....	138
Miller, J. S.....	89
Mineralogy.....	7, 9, 20, 34, 56, 76, 109
Miocene.....	105, 150
Mohs, F.....	64
Mojsisovics, E. von.....	146
Morlot, A.....	150
Mountains.....	180
buried.....	185
Münster, G.....	70
Murchison, Sir R. I.....	41, 54, 60, 75, 90, 117, 121, 126, 128, 138, 141, 144, 152, 181
Naumann, C. F.....	109
Neogene.....	151
Neptunists.....	34, 40
Neumayr, M.....	168
Newberry, J. S.....	119
New Red Sandstone.....	144
Nicol, J.....	181
Nilsson, S.....	95
Nomenclature, Palæontological.....	20, 24
Oldham, T.....	115
Old Red Sandstone.....	138
Oligocene.....	106, 150
Omalius d'Halloi.....	76, 109
Omar Khàyyám.....	7
Oppel, A.....	148
Orbigny, A. d'.....	109, 156, 163
Ordnance survey.....	114
Ordovician.....	133
Organic remains. <i>See</i> Fossils.	
Oryctology.....	88
Osborn, H. F.....	174
Otley, J.....	128
Overthrusts.....	181
Owen, G.....	10
Owen, Sir R.....	92, 120, 140, 158, 173
Owen, R. D.....	119
Packe, C.....	21
Palæolithic implements.....	176

	PAGE
Palæontographical society.....	69, 161
Palæontology.....	52, 156
Palæozoic.....	104, 145
Palissy, B.....	9
Pallas, P. S.....	29
Pander, C. H.....	95
Park, J.....	122
Parkinson, J.....	57, 88
Pattison, S. R.....	141
Peach, B. N.....	182
Peach, C. W.....	142
Pengelly, W.....	142, 176
Permian.....	144
Petrology.....	74, 182
Phillips, J.....	44, 51, 61, 145, 149, 160
Phillips, W.....	58, 73, 82, 88
Pictet, F. J.....	158
Playfair, J.....	38, 59, 80, 185
Pleistocene.....	106, 151
Pliny (elder).....	5
Pliocene.....	105, 150
Plot, R.....	13, 50, 61
Plutonists.....	36
Portlock, J. E.....	62, 113
Powell, J. W.....	119
Pre-Cambrian.....	167
Prestwich, Sir J.....	99, 118, 150, 177, 187
Prevost, C.....	92
Primary.....	102
Primitive rocks.....	18, 34, 102
Pringle, J. W.....	113
Pythagoras.....	4
Quaternary.....	150, 151
Quenstedt, F. A. von.....	148
Raised beaches.....	186
Ramsay, A. C.....	99, 158
Ray, J.....	39
Recent.....	151
Reich, O.....	97
Reid, C.....	151
Renevier, E.....	164
Rhætic.....	146

	PAGE
Verneuil, P. E. P. de.....	117
Vinci, Leonardo da.....	8
Vogt, C.....	105
Vogt, J. H. L.....	184
Volcanic phenomena.....	22, 35, 78, 80, 85, 100
Volcanic rocks.....	36, 182
Vulcanists.....	36, 40
Walcott, C. D.....	119, 123, 134, 167
Walcott, J.....	51
Walker, E.....	5
Warren, E.....	12
Waters, underground.....	88
Watts, W. W.....	185
Wealden.....	94, 149
Weaver, T.....	60
Webster, T.....	64, 89
Werner, A. G.....	33, 64, 70, 76
Wernerians.....	59, 80
Wheeler, G. M.....	119
Whewell, W.....	32, 56, 61, 83, 99
Whiston, W.....	17
Williams, H. S.....	165
Willis, B.....	166
Wollaston, W. H.....	69, 76
Wood, S. V.....	162
Wood, S. V., Jr.....	155
Woodward, A. S.....	168, 173
Woodward, H.....	169
Woodward, J.....	13, 37
Woodward, S.....	161
Xenophanes.....	4
Young, R. B.....	121
Zechstein.....	19, 34, 145
Zieten, C. H. von.....	95
Zittel, K. A. von.....	32, 156, 160
Zones.....	135, 144, 146, 149, 169

*A Selection from the
Catalogue of*

G. P. PUTNAM'S SONS



**Complete Catalogue sent
on application**

A History of the Sciences

¶ Hitherto there have been few, if any, really popular works touching the historical growth of the various great branches of knowledge. The ordinary primer leaves unexploited the deep human interest which belongs to the sciences as contributing to progress and civilization, and calling into play the faculties of many of the finest minds. Something more attractive is wanted.

¶ The above need in literature has now been met. Each volume in the *History of Sciences* is written by an expert in the given subject, and by one who has studied the history as well as the conclusions of his own branch of science. The monographs deal briefly with the myths or fallacies which preceded the development of the given science, or include biographical data of the great discoverers. Consideration is given to the social and political conditions and to the attitudes of rulers

G. P. Putnam's Sons

New York

London

A History of the Sciences

and statesmen in furthering or in hindering the progress of the given science. The volumes record the important practical application of the given science to the arts and life of civilized mankind, and also contain a carefully-edited bibliography of the subject. Each volume contains from twelve to sixteen carefully-prepared illustrations, including portraits of celebrated discoverers, many from originals not hitherto reproduced, and explanatory views and diagrams. The series as planned should cover in outline the whole sphere of human knowledge.

¶ Science is to be viewed as a product of human endeavor and mental discipline, rather than taken in its purely objective reference to facts. The essential purpose has been to present as far as practicable the historical origins of important discoveries, also to indicate the practical utility of the sciences to human life.

G. P. Putnam's Sons

New York

London

A History of the Sciences

Each volume is adequately illustrated, attractively printed, and substantially bound, and contains a complete index.

16 mo. Each, net, 75 cents. By mail, 85 cents

History of Astronomy

By George Forbes, M.A., F.R.S., M.Inst. C.E.

Formerly Professor of Natural Philosophy, Anderson's
College, Glasgow

12 Illustrations

I thank you for the copy of Forbes's *History of Astronomy* received. I have run it over, and think it very good indeed. The plan seems excellent, and I would say the same of your general plan of a series of brief histories of the various branches of science. The time appears to be ripe for such a series, and if all the contributions are as good as Prof. Forbes's, the book will deserve a wide circulation, and will prove very useful to a large class of readers.—*Extract from a letter received from Garrett P. Serviss, B.S.*

History of Chemistry

By Sir Edward Thorpe, C.B., LL.D., F.R.S.

Author of "Essays in Historical Chemistry," "Humphrey
Davy : Poet and Philosopher," "Joseph Priestly," etc.

Two vols. Vol. I—circa 2000 B.C. to 1850 A.D.

Vol. II—1850 A.D. to date

Vol. I, 12 Illustrations. Vol. II, 14 Illustrations

The author traces the evolution of intellectual thought in the progress of chemical investigation, recognizing the various points of view of the different ages, giving due credit even to the ancients. It has been necessary to curtail many parts of the History, to lay before the reader in unlimited space enough about each age to illustrate its tone and spirit, the ideals of the workers, the gradual addition of new points of view and of new means of investigation.

"A remarkably interesting account of modern chemistry."

Scientific American.

History of Old Testament Criticism

By Archibald Duff


Professor of Hebrew and Old Testament Theology in the
United College, Bradford

16 Illustrations

A brief and attractive presentation of the work of the founder of the modern method of Bible-study, with photographs and many of them.

"It is a handy compendium of the main facts."—*The Biblical World.*

"An excellent handbook."—*The Churchman.*



The History of Anthropology.

By A. C. HADDON, M.A., Sc.D., F.R.S., Lecturer in
Ethnology, Cambridge and London.

In Preparation

The History of Geography.

By Dr. JOHN SCOTT KELTIE, F.R.G.S., F.S.A., Hon.
Mem. Geographical Societies of Paris, Berlin, Rome,
Brussels, Amsterdam, Geneva, etc.

The History of Geology.

By HORACE B. WOODWARD, F.R.S., F.G.S., Assistant
Director of Geological Survey of England and Wales.

The History of New Testament Criticism.

By F. C. CONYBEARE, M.A., late Fellow and Praelector of
Univ. Coll., Oxford; Fellow of the British Academy;
Doctor of Theology, *honoris causa*, of Giessen; Officer
d'Academie.

***Further volumes are in plan on the following
subjects:***

**Mathematics and Mechanics—Molecular Physics,
Heat, Light, and Electricity—Human Physiology,
Embryology, and Heredity—Acoustics, Harmonics,
and the Physiology of Hearing, together with Optics,
Chromatics, and Physiology of Seeing—Psychology,
Analytic, Comparative, and Experimental—Sociology
and Economics—Ethics—Comparative Philology—
Criticism, Historical Research, and Legends—Com-
parative Mythology and the Science of Religions—
The Criticism of Ecclesiastical Institutions—Culture,
Moral and Intellectual, as Reflected in Imaginative
Literature and in the Fine Arts—Logic—Philosophy
—Education.**

New York G. P. Putnam's Sons London

1871



3 2044 019 881 77

A FINE IS INCURRED IF THIS BOOK IS
NOT RETURNED TO THE LIBRARY ON
OR BEFORE THE LAST DATE STAMPED
BELOW.

FEB

7 1974

44 06418

MAR

'74H

CANCELLED

3201

1972

OCT 30 '72H

CANCELLED

APR 6

STALL-STUDY

CANCELLED

WITHDRAWN

MAR 28 1996

BOOK DUE
CANCELLED

